LOW FLOW CONDITIONS IN THE LESSER SLAVE RIVER, 1999-2000

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EXECUTIVE SUMMARY

The Lesser Slave River (LSR) supplies water to municipalities, industry, and other users, and supports fisheries and recreation. It also receives treated municipal and pulp mill effluent. Flows in the LSR were extremely low within the last year, and emergency works were undertaken by users to ensure water supplies and flow maintenance in the river. As well, Alberta Environment (AENV) increased the monitoring and assessment of flow and water quality in the winter of 1999-2000. This included flow measurements, hydrologic analyses, two water quality synoptic surveys, dissolved oxygen (DO) recording, and enhanced water quality monitoring at the network site on the lower river. This document reports on those activities.

Recorded streamflow for the LSR at Slave Lake for 1988 to 2000 is provided. Flow over the outlet weir to the river was intermittent throughout mid- to late November, and virtually ceased around November 23-24, 1999. Shortly after, licensed temporary diversions restored flow and the total amount of flow past the weir from late November, 1999 to mid-April, 2000, was approximately 53,200 dam^3, equivalent to a mean daily discharge of 4.2 m^3/s for the period. A low flow analysis indicated that the 7Q10 discharge for the LSR, under the present weir outlet condition, is 7.2 m^3/s.

Water quality in the LSR normally reflects the quality of the outflow of Lesser Slave Lake. Because of the extremely low flow conditions during fall and winter 1999-2000, water quality came under more influence of tributaries and effluents than is typical. Nonetheless, many water quality variables were within water quality guidelines and were not notably affected by the effluent discharges. This included most of the 31 metals or trace elements analyzed, as well as non-filterable residue (suspended solids), some ions, resin acids and chelating agents. Some variables did not meet guidelines, but apparently for natural reasons. This included DO in some tributaries, iron and manganese in tributaries, and aluminum in tributaries and the mainstem LSR.

Some water quality variables in the LSR were increased in concentration by effluent discharges, but concentrations stayed within guidelines (or no guidelines are available for the variables). This included several ions, total dissolved solids (TDS), sulphide, boron, chromium, copper, manganese, uranium, vanadium, dissolved organic carbon, and biochemical oxygen demand (BOD). *E. coli* and fecal coliform bacteria increased somewhat due to both sewage and pulp mill effluent. Ammonia increased, mainly due to the sewage effluent.

A few variables in the LSR were affected by effluent discharges and, as a result, did not meet water quality guidelines. These were colour, cadmium, zinc, phosphorus, and nitrogen. Dissolved oxygen failed guidelines for a period in late November – early December 1999, then recovered, but was lower than normal for the rest of the winter. This was probably due to a combination of effluent discharges, streambed oxygen demand, and near-cessation of flow.

ACKNOWLEDGEMENTS

Field sampling and measurements were carried out by J. Willis, B. Jackson, R. Pickering, C. Ware, M. Hussey and others of the Monitoring Branch, Water Management Division (WMD). Slave Lake Pulp Corporation and the Town of Slave Lake provided access and assistance for effluent sampling. Laboratory analyses were carried out at the Alberta Research Council, Vegreville, at Maxxam Analytics, Calgary, at the Alberta Provincial Laboratory of Public Health, Edmonton, and the McIntyre Centre laboratory of WMD. Lesser Slave River discharge data was provided by Water Survey of Canada (WSC). Electronic data processing was done by D. LeClair and B. Halbig, and tables and graphs were prepared by B. Halbig.

ABBREVIATIONS AND ACRONYMS

AENV	Alberta Environment
ASWQG	Alberta Surface Water Quality Guideline
BOD	Biological oxygen demand
CCME	Canadian Council of Ministers of the Environment
COD	Chemical oxygen demand
d/s	Downstream
dam^3	Cubic decametres. 1 dam^3 = 1000 m^3
DO	Dissolved oxygen
km^2	Square kilometres
LSR	Lesser Slave River
m^3/s	Cubic metres per second
mg/L	Milligrams per Litre
mm	Millimetres
MTRN	Medium Term River Network
N	Nitrogen
P	Phosphorus
QC	Quality control
SLPC	Slave Lake Pulp Corporation
SOD	Sediment oxygen demand
STP	Sewage treatment plant
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TP	Total phosphorus
u/s	Upstream
µg/L	Micrograms per Litre
VMV	Valid Method Variable
WMD	Water Management Division
WSC	Water Survey of Canada

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1.0 INTRODUCTION

The Lesser Slave River supplies water to municipalities, industry, and other users, and supports fisheries and recreation. It receives treated municipal effluent from the town of Slave Lake, via Sawridge Creek, and treated pulp mill effluent from Slave Lake Pulp Corporation (SLPC) downstream of Mitsue Bridge (Figure 1). Flows in the Lesser Slave River have been extremely low within the last year, and emergency works have been undertaken by users to ensure water supplies and flow maintenance in the river. Monitoring of flow and water quality in the river was enhanced in November 1999 because of this situation.

Streamflow has been gauged on the Lesser Slave River at or near the outflow of Lesser Slave Lake at various times and locations as early as 1915. Streamflow in the river is currently measured at the Water Survey of Canada (WSC) gauging station 07BK001, situated at the outlet weir, just downstream of the Highway 88 bridge. Lesser Slave Lake levels (WSC station 07BJ006) are measured at the Town of Slave Lake water intake, located at the outlet of the Lake. Lake levels have similarly been recorded as early as 1915, at various sites throughout the period of record. Prior to 1984, outflow from the lake into the Lesser Slave River was unaffected by human activity. A fixed-crest weir and downstream channel improvements were completed in 1984, resulting in departure from the natural outflow from Lesser Slave Lake.

Streamflow has been measured at the present weir location since 1988. Figure 2 shows the mean monthly flow ranges for the period of record. Note that due to the large surface area of Lesser Slave Lake and the large drainage area (13,575 km^2) that supplies the lake, the flow in the river does not fluctuate widely on a seasonal basis, compared to what is typically observed in other rivers and streams. This is due to the buffering effect of the lake, which not only dampens runoff events that occur during the year, but also provides longer-term attenuation from one year to the next.

Previous Alberta Environment (AENV) water quality monitoring on the LSR has included two 'Medium Term River Network' (MTRN) sites: at the outflow of Lesser Slave Lake; and near the confluence with the Athabasca River. In addition, 'synoptic' surveys were conducted during the winters of 1990-96, and dissolved oxygen (DO) has been recorded near the Athabasca River confluence during the winters of 1989-97. During the winter of 1999-2000, the lower MTRN site was maintained, two synoptic surveys were carried out, and DO recording was re-instated. As well, measurements of streambed oxygen demand (SOD) were made, open water leads were mapped, and a review of water quality models for DO was contracted. The latter projects were carried out to support potential DO modelling at a later date.

This report compiles the AENV and WSC data from the recent discharge monitoring, synoptic surveys, DO recording, and MTRN sites. Water quality data for the recent low flow conditions

are summarized, interpreted, and compared to water quality guidelines. For water quality variables of concern, data from previous monitoring are also presented, in order to better describe the longer term conditions in the LSR. In addition, a low flow frequency analysis calculating a 7Q10[1] discharge was undertaken to assess the recent low lake levels/low flow conditions within a historical context, and to support an evaluation of water quality-based effluent limits by AENV-Environmental Services.

2.0 METHODS - GENERAL

The work covered in this report includes hydrometric monitoring, water quality synoptic surveys, DO monitoring, and MTRN site monitoring. This section provides an overview of the methods used in the work. Detailed descriptions of the methods are also available from AENV.

The hydrometric monitoring consists mainly of the regular streamflow and lake level monitoring that is routinely conducted and published by WSC. Due to the presence of siphons and the removal of one fishway at the weir during the winter of 1999-2000, the existing rating curve at the weir was not valid. Periodic site measurements were conducted to ensure that a new rating curve was established and that the flow record was correct. An important note to remember when interpreting the streamflow measurements is that the streamflow data, as published, consist of the ***total*** flow over the weir. The available data is insufficient to separate the flow amongst the various components, i.e., flow that occurred through the siphons and fishway, and the flow that may have occurred naturally had emergency measures not been adopted. However, it is reasonable to assume that the majority of flow occurring from November 25 until the spring of 2000 was facilitated by the temporary diversions, recognizing that a minimal amount of natural flow might still have occurred.

Water quality synoptic surveys were carried out in December 1999 and March 2000. Twelve sites were sampled, including the LSR, effluents, and tributaries (Figure 1). During these surveys, sampling started at the upstream-most site, and progressed downstream at approximately the river's time of travel. This approach allows sampling of a 'parcel' of water, more or less, as it moves downstream and receives effluent and tributary inflows. An extensive list of variables was sampled, with particular emphasis on those relevant to sewage and pulp mill effluents. The actual times, locations, and variables are listed with the compiled data in Table 1.

The two MTRN sites have been operated on the LSR for most of the 1990's. Sampling has been conducted approximately six times per year, for a set of variables similar to those sampled during the synoptic surveys. The recording oxygen meters have been installed under the ice near the Athabasca

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[1] The 7Q10 discharge is defined as the low flow, averaged over a 7-day period, that would be expected to occur once every ten years.

River confluence during most winters in the 1990's. As well as DO, the meters record temperature, pH, and conductance.

Laboratory analyses were carried out at: the Alberta Research Council, Vegreville; Maxxam Analytics, Calgary; the Alberta Provincial Laboratory of Public Health, Edmonton; and at the McIntyre Centre lab of WMD. For the synoptic surveys, the VMV codes for the analytical methods used are included with the column headers in Table 1. Full descriptions of these are available from AENV or the Environment Canada website.

Standard quality control (QC) measures were taken throughout the work and included proper field sampling gear and procedures, laboratory QC measures, and the submission of blind replicate and field blank samples. Details are available from AENV and the results of replicate and blank samples are included in Table 1. All data were subject to regular AENV validation procedures. Data were downloaded from the Water Data System, and compiled into tables and figures. Mass flux, or 'load', was calculated from concentration and discharge data. For graphing and load calculations, values less than the detection limit were taken to be ½ the detection limit. To evaluate water quality conditions, concentration data were compared to the *Surface Water Quality Guidelines for use in Alberta* (ASWQG) (AENV 1999).

3.0 RESULTS AND DISCUSSION

3.1 HYDROMETRIC

The Hydrology/Forecasting Section of Water Sciences Branch completed an initial assessment of the impact of diversions in April of 2000. Figure 3 shows the recorded streamflow for the Lesser Slave River at Slave Lake for 1988 to 2000 (2000 data are considered preliminary, and may be subject to revision). The outlet weir had intermittently cut off flow to the river throughout mid- to late November of 1999, depending upon wind set-up conditions on the lake. This eventually culminated in near-complete cessation of flow around November 23-24, 1999. At about this time, the temporary license to divert water was issued and the emergency measures were implemented to restore flow to the downstream system.

The total amount of flow past the weir occurring from November 25, 1999 to April 18, 2000, was approximately 53,200 dam^3. This volume is equivalent to a mean daily discharge of 4.2 m^3/s for the period, or about 46 mm of depth on the lake. Levels remained relatively stable throughout the winter, indicating that the combination of snow and ice on the lake, and winter inflow from upstream tributaries, was sufficient to maintain lake levels while the diversion remained in place. Spring runoff in the watershed for 2000 was essentially complete by the beginning of April. As in much of the Province, runoff was virtually negligible, and the lake levels did not increase appreciably. The lake has since

responded to precipitation that has occurred in May and June, restoring the lake levels to some degree but remaining well below average for early summer.

A low flow analysis conducted by the Hydrology/Forecasting Section and reported separately (Seneka, 2000) indicated that the 7Q10 discharge for the Lesser Slave River, under the present weir outlet condition, is 7.2 m^3/s. This represented a large departure from the previously calculated value of 11.6 m^3/s, however, the change was not solely attributable to the recent low flow event. Instead, a combination of several factors, including the impact of the weir on the outlet rating curve and a longer period of record, resulted in the lower value.

Discharge data for the times and sites sampled during the synoptic surveys are compiled in Table 1. Discharge appeared to decline down the mainstem of the LSR during both surveys, by about 20-25 %, despite some inflow from tributaries. Water withdrawals by licenced users were probably not enough to account for all of these losses. The apparent decline in discharge is likely due to some combination of water loss due to ice formation (particularly in December 1999), non-steady state flow in the river, consumptive withdrawals, and measurement inaccuracy during winter ice conditions.

3.2 WATER QUALITY

Water quality in the Lesser Slave River is normally determined in large part by the quality of the outflow of Lesser Slave Lake. Because of the extremely low flow conditions this past fall and winter, water quality came under more influence of tributaries and effluents than is usually the case. The following is a synopsis of conditions within the recent fall-winter period, particularly with respect to any effects of effluents and tributaries. Water quality of the LSR is also compared to water quality guidelines (AENV 1999). The data for the two synoptic surveys, along with water quality guidelines, are compiled in Table 1. As well, graphs are provided for selected variables. These show concentrations and loads (= mass flux) for the sampling points down the river system during the synoptic surveys, and also show concentrations at the two MTRN sites during the 1990's.

3.2.1 General

Many water quality variables were within water quality guidelines and were not notably affected by effluent discharges during fall-winter, 1999-2000. This included most of the 31 metals or trace elements analyzed, as well as non-filterable residue (suspended solids), some ions, resin acids and chelating agents (Table 1).

The resin acids (palustric through 12,14-dichloro-dehydro-abietic acid in the tables of Table 1) are common by-products of pulp mills and can account for much of the toxicity of untreated mill effluents. However, they are efficiently degraded by effluent treatment, and have generally been at low

levels in the river downstream of the pulp mill effluent in the 1990's (Table 2). Those levels, approximately 1 μg/L or less, are well within the water quality guideline of 100 μg/L for total resin acids.

Chelating agents are also listed in Table 2. They are used in the industrial process in the pulp mill and are detectable in the mill effluent (Table 1). They have not been detected in the LSR since monitoring began in the early 1990's.

Some variables did not meet water quality guidelines, but apparently for natural reasons. This included:

- Dissolved oxygen in the Otauwau and Saulteaux rivers, tributaries to the LSR.
- Iron and manganese in tributaries; aluminum in tributaries and the mainstem Lesser Slave River; lead in occasional samples from the mainstem.
- Mercury (total) in the Lesser Slave River also exceeded the very stringent draft Alberta guideline, but not the CCME (Canadian Council of Ministers of the Environment) guideline for protection of aquatic life. The actual concentrations were quite low and mercury was also detectable in the field blank. Further investigation would be necessary to confirm mercury concentrations in the river.

3.2.2 Effects Not Exceeding Guidelines

Some water quality variables in the LSR were increased in concentration by effluent discharges, but concentrations stayed within guidelines (or no guidelines are available for the variables). Details follow.

- Sodium, bicarbonate, sulphate, reactive silica, and total dissolved solids all increased mainly due to the pulp mill effluent. Figure 4a and b illustrate the effects of an input on river concentrations, utilizing sodium, which was high in the pulp mill effluent and is a conservative ion. 'Conservative' means that it stays dissolved in the water column and is subject to very little change due to physical, chemical, or biological processes. Figure 4c shows sodium concentrations throughout the 1990's and illustrates the effect of dilution on the sodium inputs from the pulp mill effluent. During many winters, when flows are lower than in summer, sodium concentrations rise. During the winters of 1997 and 1998, flows were much above average and sodium concentrations remained similar to upstream levels. During the winters of 1999 and 2000, flows were much below average, and sodium rose to much higher levels at the downstream site. Note that during the winter of 1990, prior to the start-up of the SLPC, there was little difference in concentration of sodium between the two sites.

- Sulphide was just detectable in the river downstream of the mill effluent during both surveys, but stayed within the guideline of 0.002 mg/L. The pulp mill effluent accounted for this (Table 1).
- Boron, copper, manganese, uranium, and vanadium increased in the river downstream of the pulp mill effluent, but remained within guidelines. Manganese was also very high in the Saulteaux River in March, and contributed to an increase in the LSR then (Table 1). The reason for the high manganese is not certain, although it could be a natural condition.
- River concentrations of chromium were increased by the pulp mill effluent during both surveys, but can not be fully evaluated because information on the form of chromium is not available, and the guidelines are specific to chromium VI. The graphs of loads (Figures 5a and b) show that the increases in river concentrations can be accounted for by the load from the pulp mill effluent. During the 1990's, chromium was occasionally higher than during the winter of 1999-2000 (Figure 5c), including a period in 1992-93 when it was notably higher at the downstream site than near the lake outflow.
- Ammonia nitrogen in the LSR was increased due to discharge of the sewage effluent (Figure 6). Concentrations stayed within the guideline which, for the pH conditions prevailing during winter, was >1 mg/L. During the 1990's, ammonia-N in winter has generally been higher at the site near the Athabasca River than at the site near the lake outflow (Figure 6c).
- Dissolved organic carbon, biochemical oxygen demand (BOD), and chemical oxygen demand (COD) increased in the lower LSR, mainly due to the pulp mill effluent, although sewage appeared to contribute some BOD (Table 1). Note that although no guidelines exist for BOD *per se,* this variable of course, strongly influences dissolved oxygen (see below).
- *Escherichia coli* and fecal coliform bacteria: The sewage effluent and perhaps also Sawridge Creek appeared to contribute these bacteria during the December synoptic survey, whereas the pulp mill effluent appeared to contribute them in March (Table 1). Guidelines for irrigation and recreational water quality were not exceeded.

3.3.3 Variables Exceeding Guidelines

A few variables in the Lesser Slave River were affected by effluent discharges and as a result exceeded water quality guidelines, during both the December 1999 and March 2000 synoptic surveys (Table 1). These included:

- <u>Dissolved oxygen:</u> Oxygen is necessary for the maintenance of aquatic life, and the applicable Alberta guidelines are 6.5 mg/L (chronic) and 5 mg/L (acute). DO monitoring was done with recording meters at the MTRN site for most of the 1999-2000 winter, and the concentrations are plotted in Figure 7a. The Alberta guidelines for DO were not met in early December 1999, prior to the first synoptic survey. The cause of the marked sag in DO then may be a combination of negligible flow in the river, BOD inputs in sewage and tributaries, upset BOD inputs from the pulp mill, and oxygen demand from the streambed (SOD). More detailed assessment, potentially including modelling, would be required to better determine the significance of each factor. After the low-DO event, flow in the river was augmented and mill effluent BOD loads declined. DO recovered and stayed above 8 mg/L for the rest of the winter. Note that during previous winters when DO has been recorded, it has always been above 10 mg/L (Figure 7a). This probably reflects the greater flow and effluent dilution during more typical winters.

  During the actual synoptic surveys, all DO concentrations in the LSR met the guidelines (Figures 7b and 7c). Note that DO declined down the river system by about 5-6 mg/L, from the weir near Slave Lake, to the confluence with the Athabasca River. During these surveys, DO at the mouth of the river was 0.8 to 1.7 mg/L lower than at the site 11.5 km upstream, where the recording DO meter was installed.

  The longer-term data (Figure 7d) show that DO is always somewhat lower in winter at the downstream end of the LSR than near the lake outflow. However, the winter of 1999-2000 was more accentuated in this regard. Note that DO is actually lower in the summer months of most years, because of the lower solubility of oxygen in warmer water.

  The effect on aquatic life of the DO sag in November-December 1999 is not presently known. SLPC carried out an effects monitoring survey in early January 2000, which may provide information relevant to this question.

- <u>Colour:</u> Colour is usually measured on a filtered sample and is then termed 'true' colour. Colour of the LSR during the two synoptic surveys was increased by the highly coloured pulp mill effluent (Figures 8a and b). The guideline for colour, which is a maximum increase of 30 units, was exceeded as a result. Excessive colour can impair the aesthetic qualities of water and can limit light penetration into water, thereby inhibiting photosynthesis during the

growing season. In the 1990's, colour has usually been highest in the LSR in summer (Figure 8c), perhaps because of higher flows entraining more organic material, and the inflow of stained tributaries. Colour has usually been higher in the lower river than near the lake outflow.

- Cadmium: During the synoptic surveys, cadmium increased in the lower LSR, mainly due to the input of the pulp mill effluent (Figure 9a and b). Although the LSR d/s of the weir was slightly above the guideline in December 1999, the mill effluent increased concentrations noticeably. The guideline for the prevailing water hardness (100 mg/L) is 0.033 µg/L (CCME 1999 in AENV 1999). It is difficult to evaluate cadmium during the 1990's because many past results were less than the analytical detection limits. Improved detection limits in recent years have allowed better evaluation of cadmium concentrations (Figure 9c).

- Zinc: Pulp mill effluent concentrations of zinc were about 1000 µg/L during the synoptic surveys, and this input caused river concentrations to rise (Figure 10a and b) and exceed the 30 µg/L guideline for the protection of aquatic life. Zinc has tended to be higher at the downstream site during the 1990's (Figure 10c), although it has not been observed to exceed the water quality guideline before.

- Phosphorus (P): Phosphorus is an important plant nutrient and excessive amounts of it may lead to increased growth of aquatic plants. Total P increased down the river during the two synoptic surveys, mainly due to pulp mill effluent, although sewage also contributed (Figures 11a and b). Concentrations exceeded the Alberta guideline, which is 0.05 mg/L. About 2/3 to 3/4 of the P was in the dissolved form throughout the river (Table 1). Phosphorus has tended to be higher at the downstream site than near the lake outflow during the 1990's (Figure 11c). Effluents may be contributing to this difference, although tributary inflows may also be significant.

- Nitrogen: As for phosphorus, nitrogen is an important plant nutrient. Total nitrogen (TN) is calculated as the sum of nitrite+nitrate nitrogen and total Kjeldahl nitrogen (TKN). The latter includes both ammonia and organic nitrogen. During the winter synoptic surveys, TN increased in the LSR (Figures 12a and b) due to both sewage effluent (mostly as ammonia) and pulp mill effluent (mostly as organic nitrogen). Although some tributaries were also high in TN, their loads were much lower than the effluent loads (Figure 12a and b). The Alberta

guideline is 1 mg/L and was exceeded downstream of the pulp mill effluent. Nitrification appeared to be occurring downstream in the river during the winter (Table 1). During the 1990's, TN was generally higher at the downstream site than upstream (Figure 12c), although gaps in the data record make this a tentative conclusion.

Overall, greater effects on water quality have occurred during winter 1999-2000, in large part due to the very low flows providing less dilution of effluents.

4.0 REFERENCES

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Canadian Council of Ministers of the Environment (CCME). 1999. Canadian environmental quality guidelines (CEQG). Environment Canada, Hull, Ottawa.

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5.0 TABLES AND FIGURES

Table 1. Lesser Slave River water quality synoptic surveys 1999-2000, and water quality guidelines.

DECEMBER 1999

Sample No.	Station No.	Latitude	Longitude	Station Description	Sample Date	River distance from mouth km	Discharge - m3/s	Water Temp 100925 Deg C	pH Field 100923 pH units	pH Lab 10301 pH units	Specific Cond. Field 100924 uS/cm	Specific Cond. Lab 2041 uS/cm	Dissolved Oxygen Field meter 100922 mg/L	Dissolved Oxygen Winkler 8101 mg/L	True Colour 2024 Rel Units	Turbidity 2074 NTU	Non Filterable Residue 10401 mg/L	Total Residue 10471 mg/L	TDS-calc. 205 mg/L	TDS 207 mg/L	PP Alkalinity 10151 mg/L	Total Alkalinity 10101 mg/L	Total Hardness 10602 mg/L	Sodium, diss. 102085 mg/L	Potassium, diss. 102086 mg/L	Calcium, tot. 101894 mg/L	Calcium, ext. 101838 mg/L	Magnesium, ext. 101847 mg/L	Bicarbonate 6201 mg/L	Carbonate 6301 mg/L	Chloride, diss. 102087 mg/L	Sulphate, diss. 16306 mg/L
99SWE05744	AB07BK0020	551819	1144510	LSR below Weir, near Outflow from Lesser Slave Lake-LB	13-Dec-99	70	4.85	-0.2	7.4	8.1	211	220	14.4	13.74	5	1.6	2	162	123	160	L1	104	95	9.5	3	28.4	27.6	6.34	127		2.1	11
99SWE05745	AB07BK0020			LSR below Weir, near Outflow from Lesser Slave Lake-LB	13-Dec-99																											
99SWE05742	AB07BK0025	551705	1144529	Sawridge Ck. at Hwy 88 Bridge u/s of Slave Lake STP Effl.	13-Dec-99	68.3	0.118	-0.3	7.2	7.1	151	159	8.7	8.25	70	19.1	4	126	86.7	122	L1	79	58	11	1.6	16.8	17.1	3.78	96		2.4	3
99SWE05740	AB07BK0360	551711	1144500	Slave Lake STP Final Effl.	13-Dec-99	68.3	0.029			7.6		787			45	10.6	10	474	434	464	L1	272	130	75.8	11.9	37.2	37.3	9.08	332		65.2	35
99SWE05741	AB07BK0360			Slave Lake STP Final Effl.	13-Dec-99																											
99SWE05756	AB07BK0030	551736	1143520	LSR at Mitsue Bridge	14-Dec-99	53.5	4.29	-0.3	7.7	7.8	216	227	13.0	12.64			3	156	136	153	L1	107	92	16.2	3.4	28.6	27.3	5.84	131		5.2	14
99SWE05757	AB07BK0030			LSR at Mitsue Bridge	14-Dec-99																											
99SWE05760	AB07BK0030			LSR at Mitsue Bridge	15-Dec-99			-0.3	7.3		215		13.0	12.44																		
99SWE05753	AB07BK0330	551510	1143225	Slave Lake Pulp Mill Final Effl.	14-Dec-99	46	0.112	26.4	8.2	8.4	5630	5550	6.6		2200	20	45	5330	3850	5280	30	2660	172	1370	58.9	49	46.6	13.5	3170	36	56.1	710
99SWE05754	AB07BK0330			Slave Lake Pulp Mill Final Effl.	14-Dec-99																											
99SWE05747	AB07BK0070	551650	1142507	LSR u/s of Otauwau R.	14-Dec-99	39	4.16	-0.3	7.8	8.0	372	380	12.2		90	3.5	4	286	225	282	L1	172	96	49.4	4.7	29.3	28.2	6.12	209		3.1	30
99SWE05748	AB07BK0070			LSR u/s of Otauwau R.	14-Dec-99																											
99SWE05750	AB07BK0075			Otauwau R. above Confl. LSR	14-Dec-99	38.6	0.084	-0.3	7.6	7.3	299	307	6.9		82	9.2	2	222	170	220	L1	156	139	12.8	1.8	40.3	39.9	9.5	191		2.8	10
99SWE05751	AB07BK0075			Otauwau R. above Confl. LSR	14-Dec-99																											
99SWE05765	AB07BK0085	551553	1141949	Saulteaux R. above Confl. LSR	15-Dec-99	32.1	0.067	-0.3	6.7	7.4	368	404	5.4	4.97	55	7.8	L1	266	220	265	L1	218	175	15.8	2.6	53.1	51.2	11.3	265		2.6	5
99SWE05766	AB07BK0085			Saulteaux R. above Confl. LSR	15-Dec-99																											
99SWE05768	AB07BK0100	551516	1141446	LSR 0.5 km u/s Confl. Driftwood R.	15-Dec-99	25	4.22	-0.3	7.6		350		10.4				3	284		282												
99SWE05769	AB07BK0100			LSR 0.5 km u/s Confl. Driftwood R.	15-Dec-99																											
99SWE05762	AB07BK0105	551516	1141422	Driftwood R. above confl. LSR	15-Dec-99	24.9	0.054	-0.3	7.4	7.7	462	488	9.1	8.62	49	8.8	4	334	268	330	L1	246	208	20.1	3	61.7	58.8	14.8	300		1.4	22
99SWE05763	AB07BK0105			Driftwood R. above confl. LSR	15-Dec-99																											
99SWE05776	AB07BK0125	551224	1140721	LSR 11.5 km u/s Athabasca R. Confl.	16-Dec-99	11.5	3.94	0.0	7.4	7.8	383	401	9.7		85	2.1	2	284	228	282	L1	178	98	46.8	4.7	31.1	29.3	6.08	217		2.8	31
99SWE05777	AB07BK0125			LSR 11.5 km u/s Athabasca R. Confl.(BOD REPL.)	16-Dec-99																											
99SWE05778	AB07BK0125			LSR 11.5 km u/s Athabasca R. Confl.(TRUE SPLIT #2)	16-Dec-99					7.8		401			85	2.2	2	284	228	282	L1	177	98	47.2	4.7	30.8	29.2	6.09	216		3.7	30
99SWE05779	AB07BK0125			LSR 11.5 km u/s Athabasca R. Confl.(TRUE SPLIT #3)	16-Dec-99					7.8		401			85	2.2	3	284	227	282	L1	178	98	47.9	4.7	30.6	29.3	6.13	217		2.8	29
99SWE05783	AB07BK0130	550957	1140343	LSR near Confluence with Athabasca R	20-Dec-99	0.5		0.1	7.2		414		8.0																			
99SWE05784	AB07BK0130			LSR near Confluence with Athabasca R	20-Dec-99																											
99SWE05780	AB10CA0001			Field Blank	16-Dec-99					5.7		1.1			L1	L0.01	L1	2	5.2	2	L1	2	L1	1.4	L0.1	L0.01	L0.01	L0.003	3		0.4	L3
				Water Quality Guideline and Value - most stringent (for the Protection of Aquatic Life (PAL), unless noted):				AWQG not increased more than 3 °C above ambient temperature	AWQG 6.5-8.5				AWQG 5.0 (1-day min.) 6.5 (7-day mean)		AWQG not increased more than 30 TCU	CEQG flow, background level dependent	AWQG not increased more than 10 mg/L		CEQG-AGR(Irr) 500-3500 mg/L			USEPA 20 mg/L minimum				CEQG-AGR(Live) 1000 mg/L					CEQG-AGR(Irr) 100-700 mg/L	CEQG-AGR(Live) 1000 mg/L

MARCH 2000

Sample No.	Station No.	Latitude	Longitude	Station Description	Sample Date	River distance from mouth km	Discharge - m3/s	Water Temp 100925 Deg C	pH Field 100923 pH units	pH Lab 10301 pH units	Specific Cond. Field 100924 uS/cm	Dissolved Oxygen Field meter 100922 mg/L	Dissolved Oxygen Winkler 8101 mg/L	True Colour 2024 Rel Units	Turbidity 2074 NTU	Non Filterable Residue 10401 mg/L	Total Residue 10471 mg/L	TDS-calc. 100536 mg/L	TDS 207 mg/L	PP Alkalinity 10151 mg/L	Total Alkalinity 10101 mg/L	Total Hardness 10602 mg/L	Sodium, diss. 102085 mg/L	Potassium, diss. 102086 mg/L	Calcium, tot. 101894 mg/L	Calcium, ext. 101838 mg/L	Magnesium, ext. 101847 mg/L	Bicarbonate 6201 mg/L	Carbonate 6301 mg/L	Chloride, diss. 102087 mg/L	Sulphate, diss. 16306 mg/L
00SWE00401	AB07BK0020	551819	1144510	LSR below Weir, near Outflow from Lesser Slave Lake-LB	06-Mar-00	70	4.350	0.5	7.9	7.9	225	13.4	13.3	10	0.6	L1	158	130	158	L1	107	101	11	3.2	29.2	29.4	6.7	130		2.2	13
00SWE00402	AB07BK0020			LSR below Weir, near Outflow from Lesser Slave Lake-LB	06-Mar-00																										
00SWE00403	AB07BK0025	551705	1144529	Sawridge Ck. at Hwy 88 Bridge u/s of Slave Lake STP Effl.	06-Mar-00	68.3	0.136	0.1	7.6	7.2	126	9.9	9.72	54	16.7	3	122	88	119	L1	62	43	7.6	1.7	13.1	12.5	2.72	76		13.7	L3
00SWE00398	AB07BK0360	551711	1144500	Slave Lake STP Final Effl.	06-Mar-00	68.3	0.031	2.0	7.5	7.6	891	7.6		52	7	11	568	499	557	L1	286	143	100	13	39	40.9	9.98	349		87.1	39
00SWE00399	AB07BK0360			Slave Lake STP Final Effl.	06-Mar-00																										
00SWE00406	AB07BK0030	551736	1143520	LSR at Mitsue Bridge	07-Mar-00	53.5	3.610	0.0	7.7		224	12.5	12.5			4									29.7						
00SWE00407	AB07BK0030			LSR at Mitsue Bridge	07-Mar-00																										
00SWE00414	AB07BK0330	551510	1143225	Slave Lake Pulp Mill Final Effl.	07-Mar-00	46	0.125	25.2	8.3	8.1	3100	6.9		1840	21	94	2880	2150	2780	L1	1560	198	749	45.4	54.3	54.6	15	1910		32.3	318
00SWE00414	AB07BK0330			Slave Lake Pulp Mill Final Effl.	07-Mar-00																										
00SWE00412	AB07BK0070	551650	1142507	LSR u/s of Otauwau R.	07-Mar-00	39	3.930	0.3	7.9	7.9	335	11.7	11.14	69	2.7	3	254	207	251	L1	158	102	42	4.9	29.4	29.9	6.73	192		3.7	24
00SWE00413	AB07BK0070			LSR u/s of Otauwau R.	07-Mar-00																										
00SWE00409	AB07BK0075			Otauwau R. above Confl. LSR	07-Mar-00	38.6	0.126	0.0	7.3	7.3	269	5.5	5.19	43	12	L1	198	156	197	L1	143	117	4.1	1.7	34.9	34	7.87	174		6	6
00SWE00410	AB07BK0075			Otauwau R. above Confl. LSR	07-Mar-00																										
00SWE00438	AB07BK0085	551553	1141949	Saulteaux R. above Confl. LSR	08-Mar-00	32.1	0.064	0.2	6.7	7.3	582	2.7	1.88	24	2.6	1	406	323	405	L1	335	270	8.9	3.2	78	78	18.2	408		1.7	L3
00SWE00439	AB07BK0085			Saulteaux R. above Confl. LSR	08-Mar-00																										
00SWE00441	AB07BK0100	551516	1141446	LSR 0.5 km u/s Confl. Driftwood R.	08-Mar-00	25	4.040	0.2	7.4		338	9.9	9.27			1															
00SWE00442	AB07BK0100			LSR 0.5 km u/s Confl. Driftwood R.	08-Mar-00																										
00SWE00444	AB07BK0105	551516	1141422	Driftwood R. above confl. LSR	08-Mar-00	24.9	0.132	0.2	7.2	7.6	306	9.2		36	5.3	2	252	174	250	L1	154	142	11.6	3.2	40.3	40	10.2	188		1.7	12
00SWE00445	AB07BK0105			Driftwood R. above confl. LSR	08-Mar-00																										
00SWE00451	AB07BK0125	551224	1140721	LSR 11.5 km u/s Athabasca R. Confl.	09-Mar-00	11.5	3.290	0.2	7.5	7.6	335	9.2	8.35	65	2.1	1	250	199	249	L1	159	106	35.2	4.6	30.8	31.1	7	194		3.3	21
00SWE00452	AB07BK0125			LSR 11.5 km u/s Athabasca R. Confl.	09-Mar-00																										
00SWE00448	AB07BK0130	550957	1140343	LSR near Confluence with Athabasca R	09-Mar-00	0.5		0.2	7.5		334	8.4	7.49																		
00SWE00449	AB07BK0130			LSR near Confluence with Athabasca R	09-Mar-00																										
00SWE00454	AB10CA0001			Field Blank	09-Mar-00					5.5				L1	0.06	L1	L1	6.2	L1	L1	2	L1	1.9	L0.1	L0.01	L0.01	0.005	2		0.9	L3
00SWE00455	AB10CA0001			Field Blank	09-Mar-00																										

Project: ABS076
Discharges: Effluents and the weir are mean daily. Others are instantaneous.
AWQG: Alberta Surface Water Quality Guidelines (1999)
CEQG: Canadian Environmental Quality Guidelines (CCME) (1999)
-AGR: Agriculture, Irr (Irrigation), Live (Livestock)
-REC: Recreation,
USEPA: United States Environmental Protection Agency (1999) - in AENV 1999.

Table 2. Resin acid and chelating agent analyses for the Lesser Slave River, 1989-1998

			RESIN ACIDS - ug/L													CHELATING AGENTS - mg/L	
Sample No.	Station No.	Sample Date	Palustric Acid	Abietic Acid	Dehydroabietic Acid	Isopimaric Acid	Levopimaric Acid	Neoabietic Acid	Pimaric Acid	Sandaracopimaric Acid	12-Chlorodehydroabietic Acid	14-Chlorodehydroabietic Acid	12,14-Dichlorodehydroabietic Acid	Chlorodehydroabietic Acid	Dichlorodehydroabietic Acid	Ethylene Diamine Tetra-Acetic Acid-EDTA	Diethyl Triamine Penta-Acetic Acid-DTPA
LESSER SLAVE RIVER AT BRIDGE NEAR OUTFLOW FROM LESSER SLAVE LAKE																	
95AB004962	AB07BK0010	21-Feb-95	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
96AB001822	AB07BK0010	20-Feb-96	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
LESSER SLAVE RIVER AT MITSUE BRIDGE																	
91AB000193	AB07BK0030	19-Feb-91														L0.1	L0.1
93AB000183	AB07BK0030	23-Feb-93														L0.1	L0.1
95AB004963	AB07BK0030	21-Feb-95	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
96AB001823	AB07BK0030	20-Feb-96	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
LESSER SLAVE RIVER UPSTREAM OF THE OTAUWAU RIVER																	
89AB007974	AB07BK0070	19-Oct-89	L10	L10	L10	L10		L10	L10	L10				L10	L10		
90AB000137	AB07BK0070	17-May-90														L0.1	L0.1
91AB000195	AB07BK0070	21-Feb-91														L0.1	L0.1
91AB006586	AB07BK0070	21-Feb-91	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
LESSER SLAVE RIVER NEAR CONFLUENCE WITH ATHABASCA RIVER																	
90AB000146	AB07BK0130	17-Oct-90														L0.1	L0.1
91AB000199	AB07BK0130	10-Jan-91														L0.1	L0.1
91AB000200	AB07BK0130	07-Feb-91														L0.1	L0.1
91AB000202	AB07BK0130	21-Feb-91														L0.1	L0.1
91AB006589	AB07BK0130	21-Feb-91	L2	L1	0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
91AB000204	AB07BK0130	11-Mar-91														L0.1	L0.1
91AB000205	AB07BK0130	10-May-91														L0.1	L0.1
91AB000206	AB07BK0130	27-Aug-91														L0.1	L0.1
92AB000186	AB07BK0130	14-Jan-92														L0.1	L0.1
92AB008047	AB07BK0130	12-Feb-92	L2	L1	0.16	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
92AB000190	AB07BK0130	19-Mar-92														L0.1	L0.1
92AB008458	AB07BK0130	19-Mar-92	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
92AB000191	AB07BK0130	05-May-92														L0.1	L0.1
92AB000192	AB07BK0130	14-Jul-92															L0.1
92AB000193	AB07BK0130	08-Oct-92														L0.1	L0.1
92AB008459	AB07BK0130	08-Oct-92	L2	L1	0.23	L0.2	L2	L2		L0.3	L0.2	L0.2	L0.2				
93AB000187	AB07BK0130	05-Jan-93														L0.1	L0.1
93AB000189	AB07BK0130	24-Feb-93														L0.1	L0.1
93AB008128	AB07BK0130	24-Feb-93	L2	1.67	L0.2	L0.2	L2	L2	0.08	L0.3	L0.2	L0.2	L0.2				
93AB000191	AB07BK0130	15-Mar-93														L0.1	L0.1
93AB000192	AB07BK0130	11-May-93														L0.1	L0.1
93AB008129	AB07BK0130	06-Oct-93	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
94AB000211	AB07BK0130	19-Jan-94														L0.1	L0.1
94AB000212	AB07BK0130	23-Feb-94														L0.1	L0.1
94AB007312	AB07BK0130	23-Feb-94	L2	L1	0.05	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	0.02				
94AB000216	AB07BK0130	16-Mar-94														L0.1	L0.2
95AB004964	AB07BK0130	22-Feb-95	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
96AB001824	AB07BK0125	21-Feb-96	L2	L1	L0.2	L0.2	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				
98SWE00086	AB07BK0125	11-Feb-98	L2	L1	L0.2	0.5	L2	L2	L0.2	L0.3	L0.2	L0.2	L0.2				

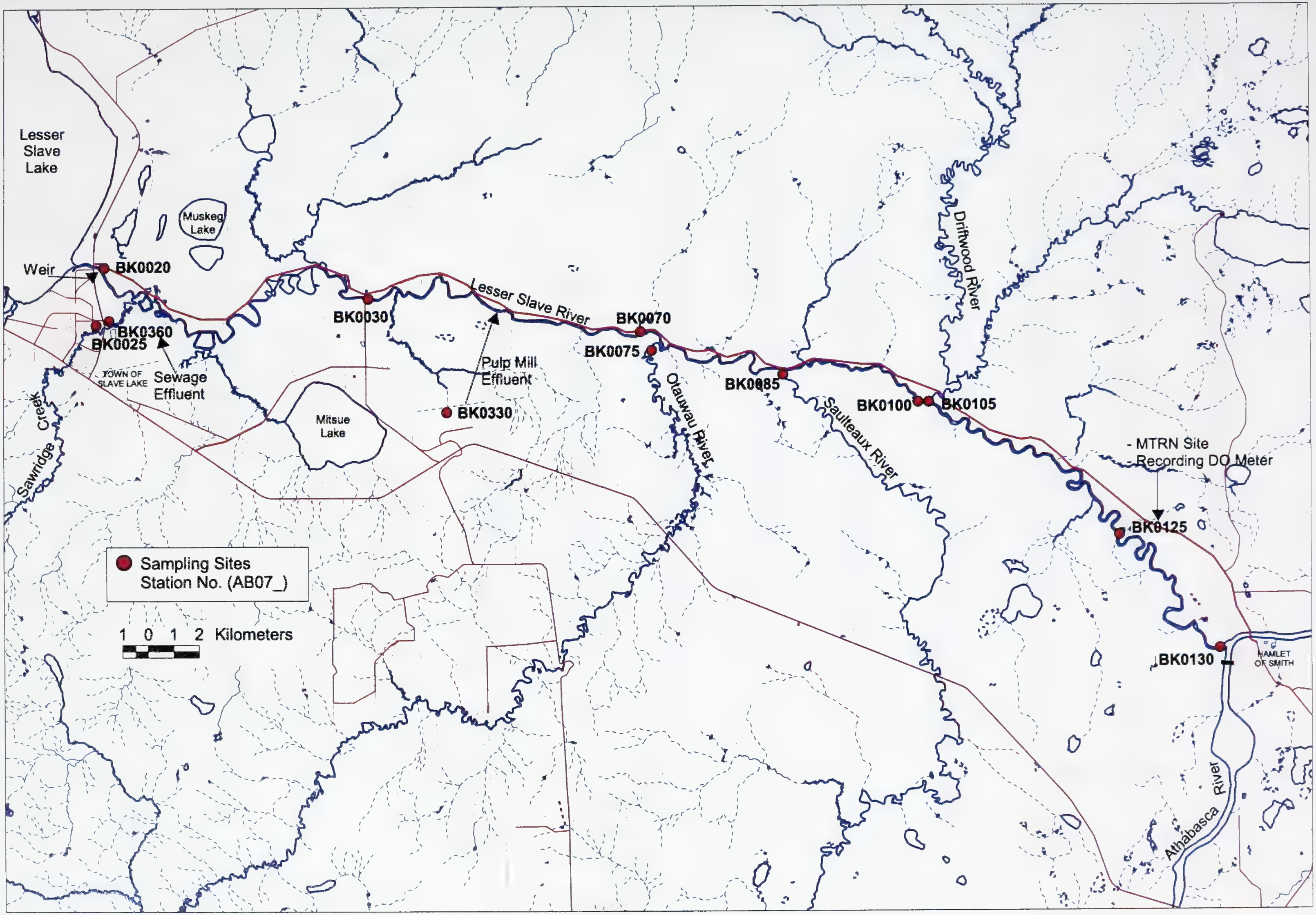
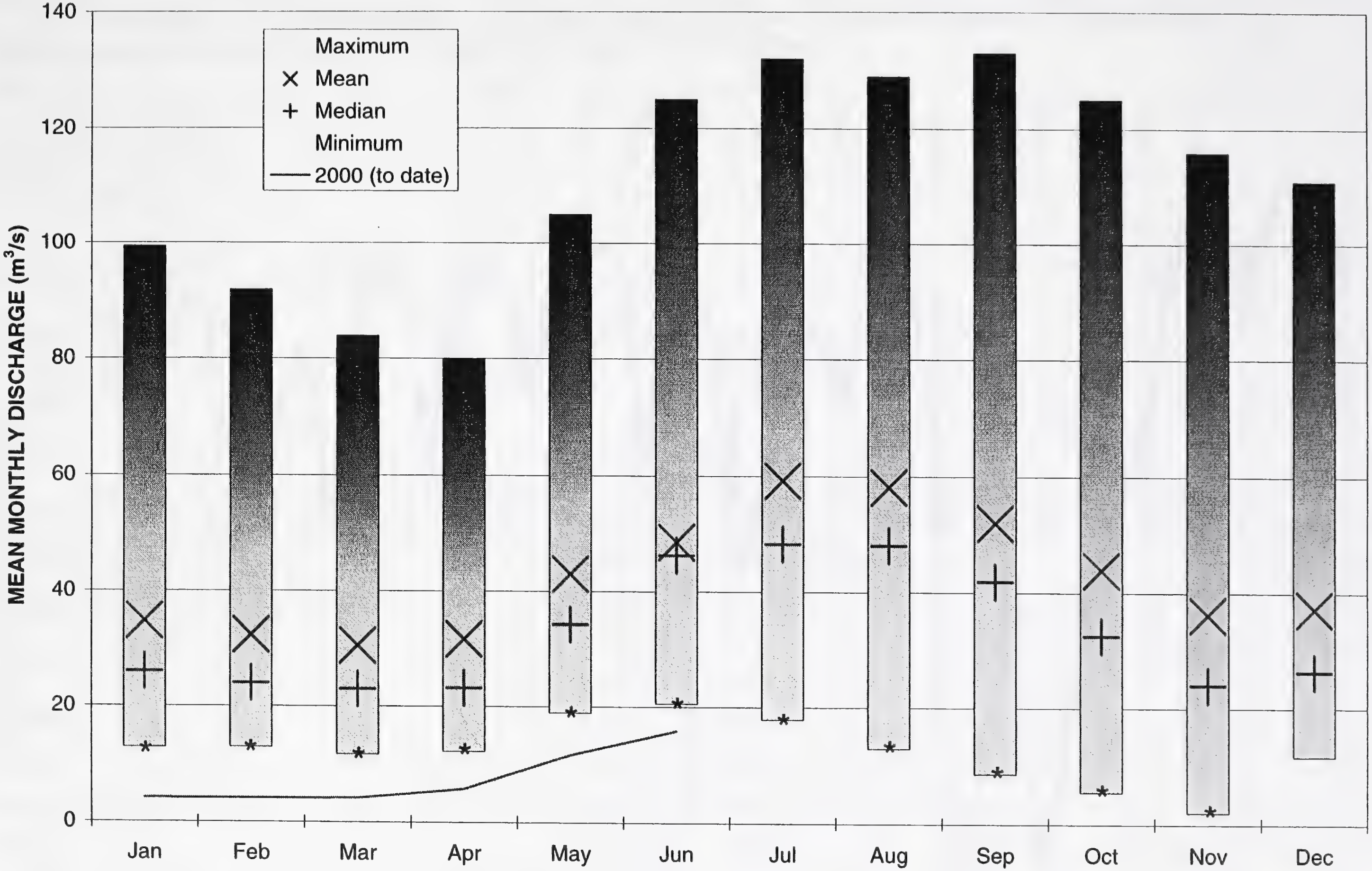


Figure 1. Lesser Slave River system with water quality sampling sites, 1999-2000.



* Minimums occurred during 1999. December 1999 data has been excluded, as flow was affected by human intervention.

Figure 2. Historical monthly discharge statistics, Lesser Slave River at Slave Lake (07BK001).
(For the available period of record after the construction of Lesser Slave Lake weir. 2000 data considered preliminary.)

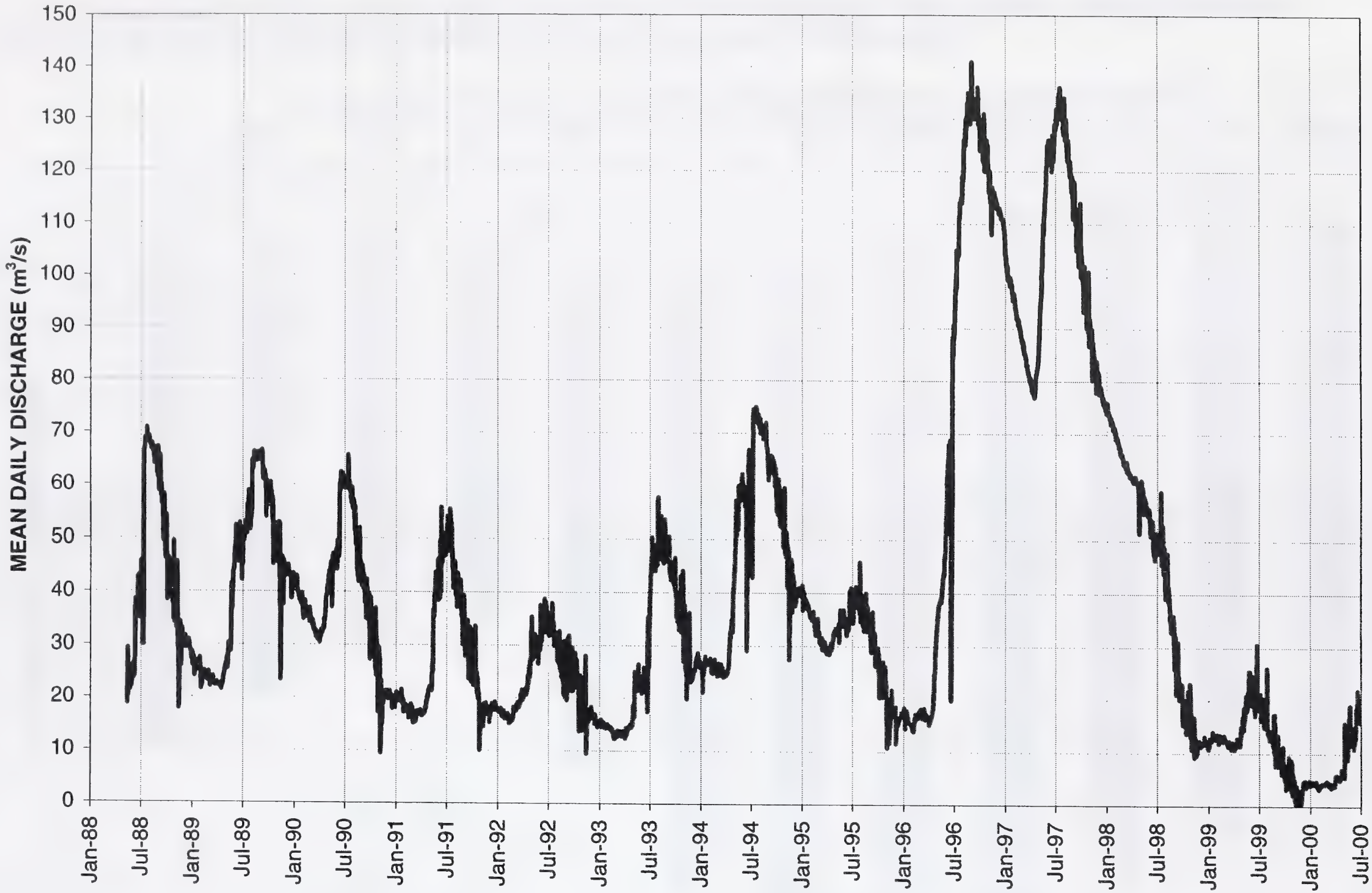


Figure 3. Historical daily streamflow, Lesser Slave River at Slave Lake (07BK001).
(For the available period of record after the construction of Lesser Slave Lake weir. 2000 data considered preliminary.)

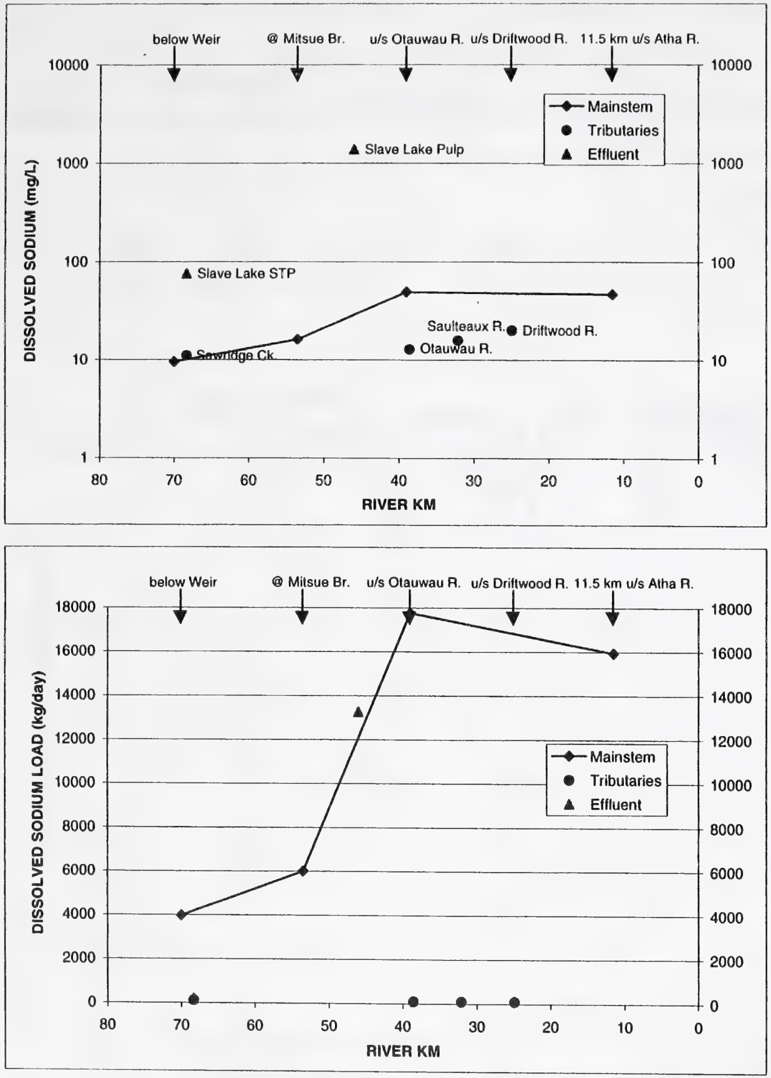


Figure 4a. Concentration and mass load of sodium during the synoptic survey of the Lesser Slave River, December 1999.

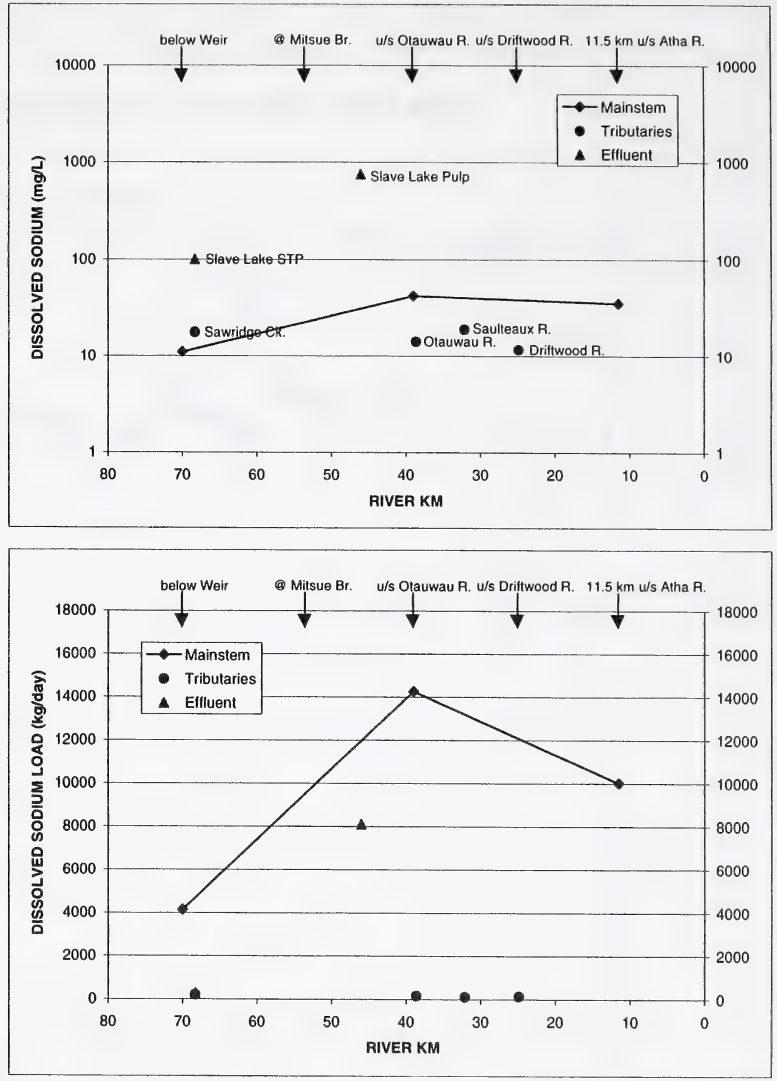


Figure 4b. Concentration and mass load of sodium during the synoptic survey on the Lesser Slave River, March 2000.

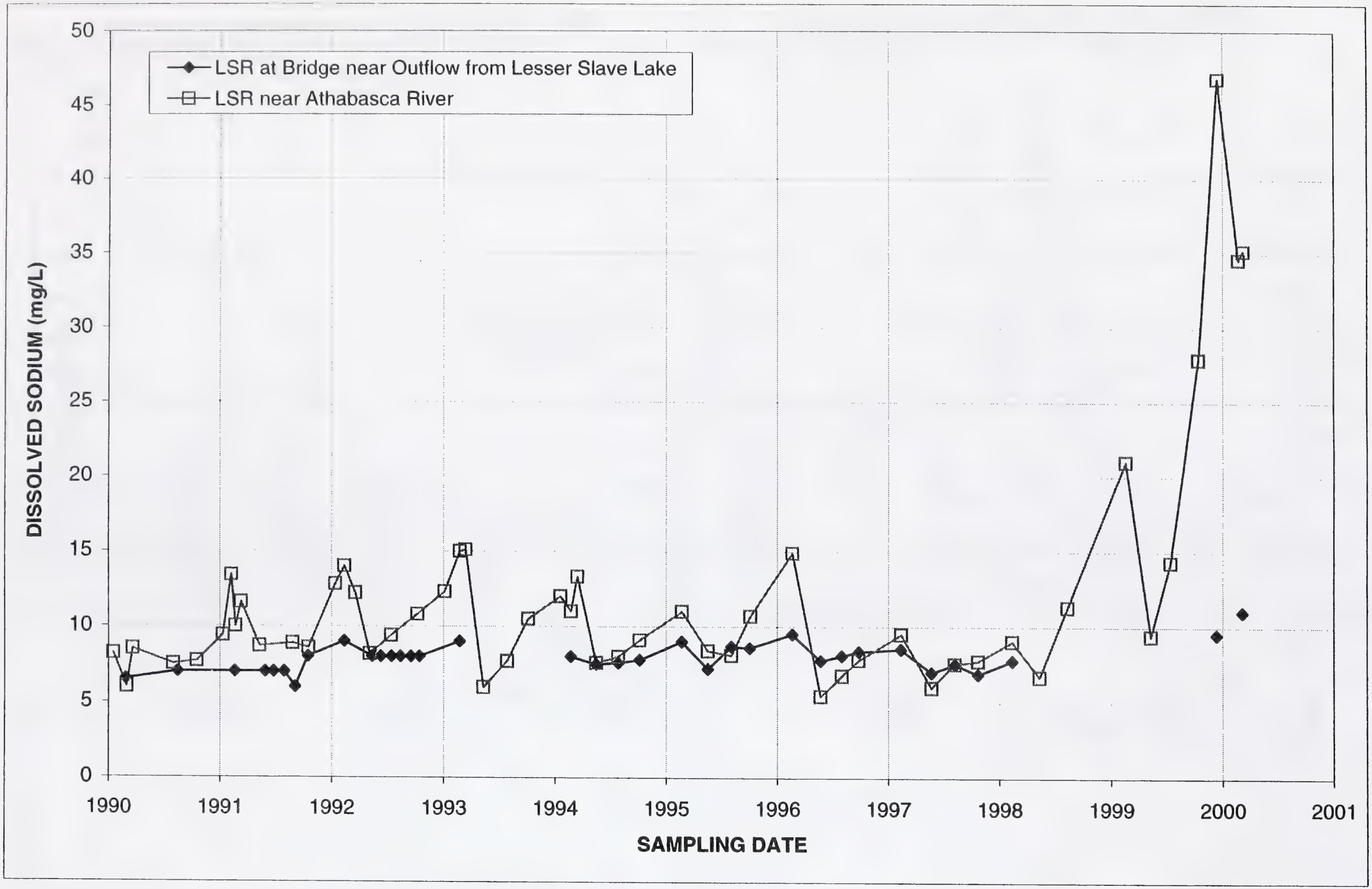


Figure 4c. Concentration of dissolved sodium at two long-term sites on the Lesser Slave River, 1990-2000.

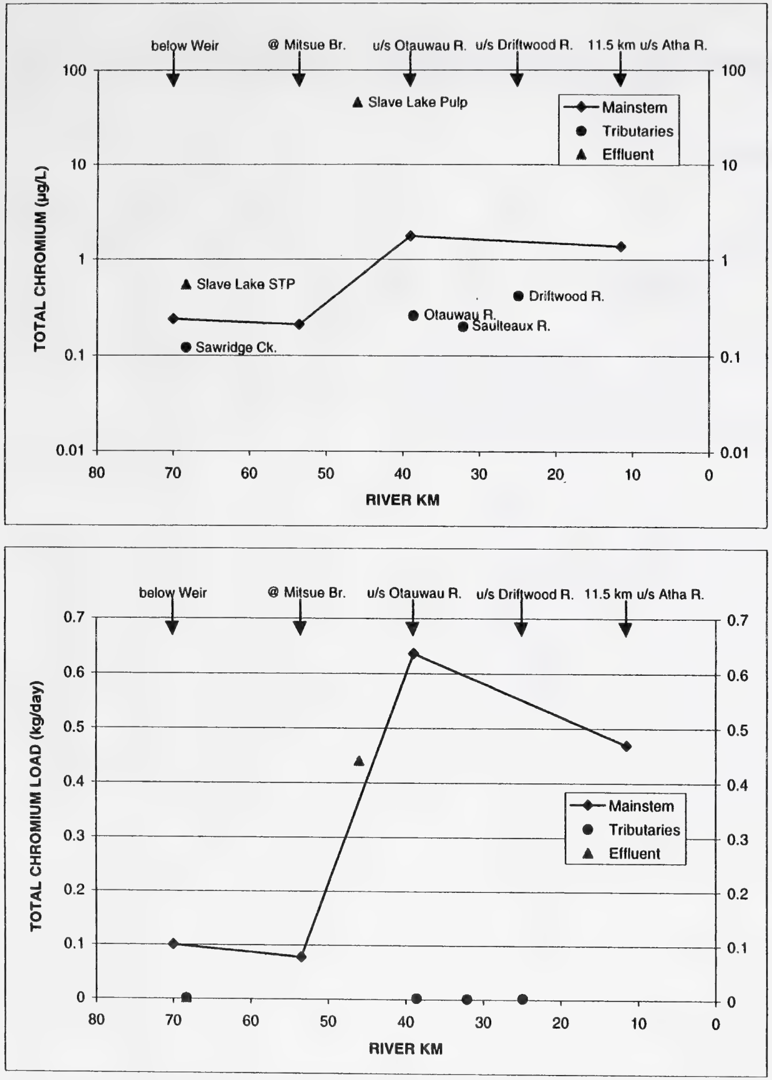


Figure 5a. Concentration and mass load of chromium during the synoptic survey of the Lesser Slave River, December 1999.

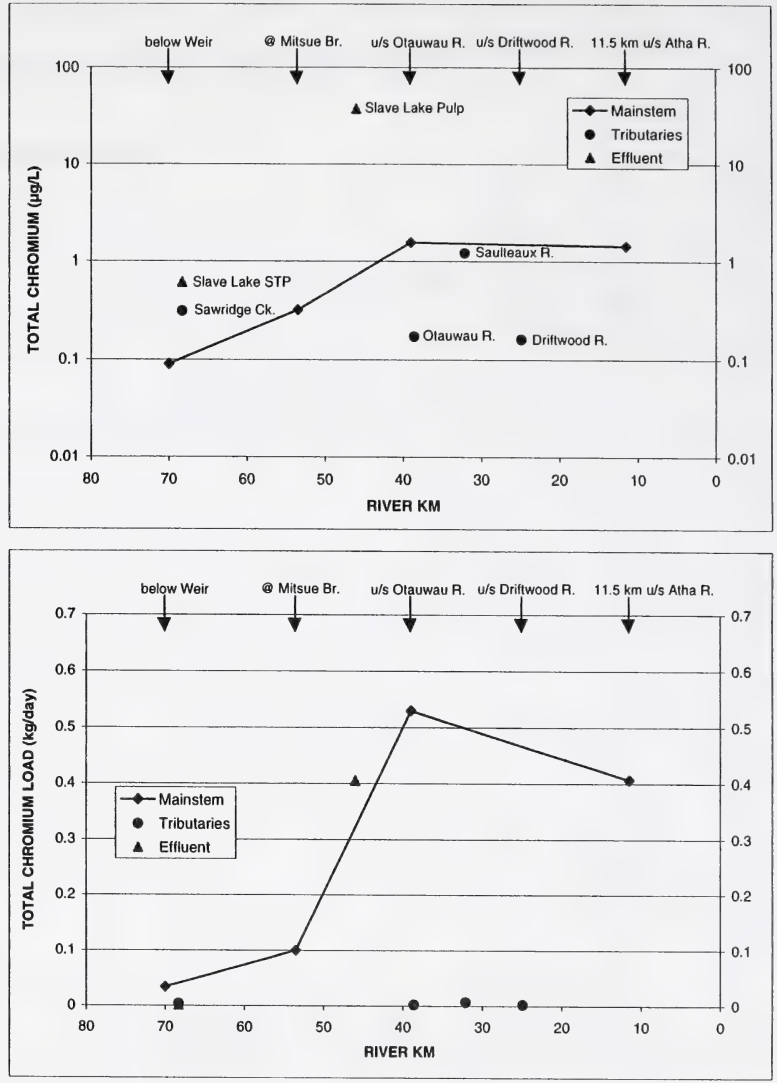


Figure 5b. Concentration and mass load of chromium during the synoptic survey on the Lesser Slave River, March 2000.

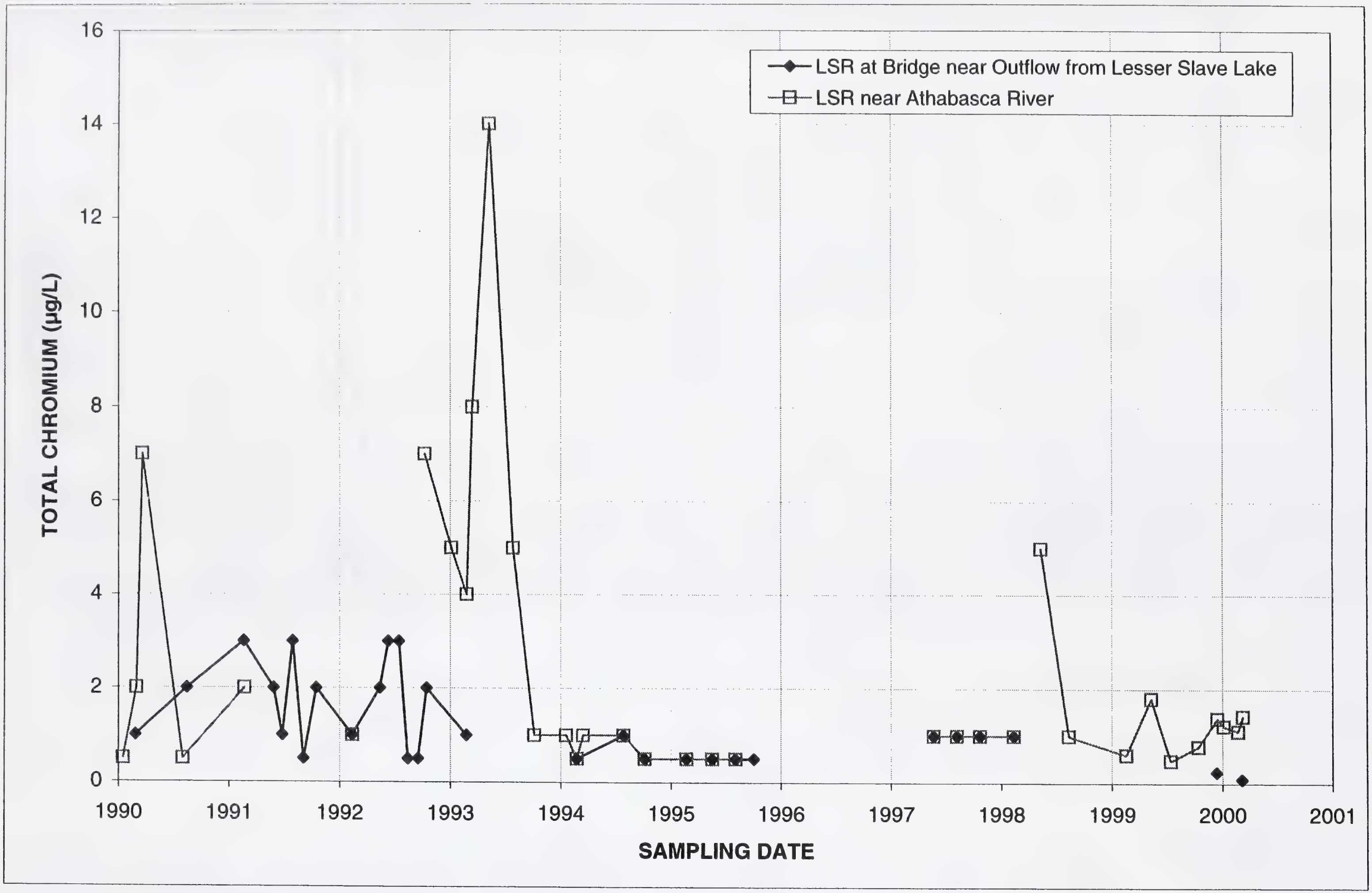


Figure 5c. Concentration of total chromium at two long-term sites on the Lesser Slave River, 1990-2000.

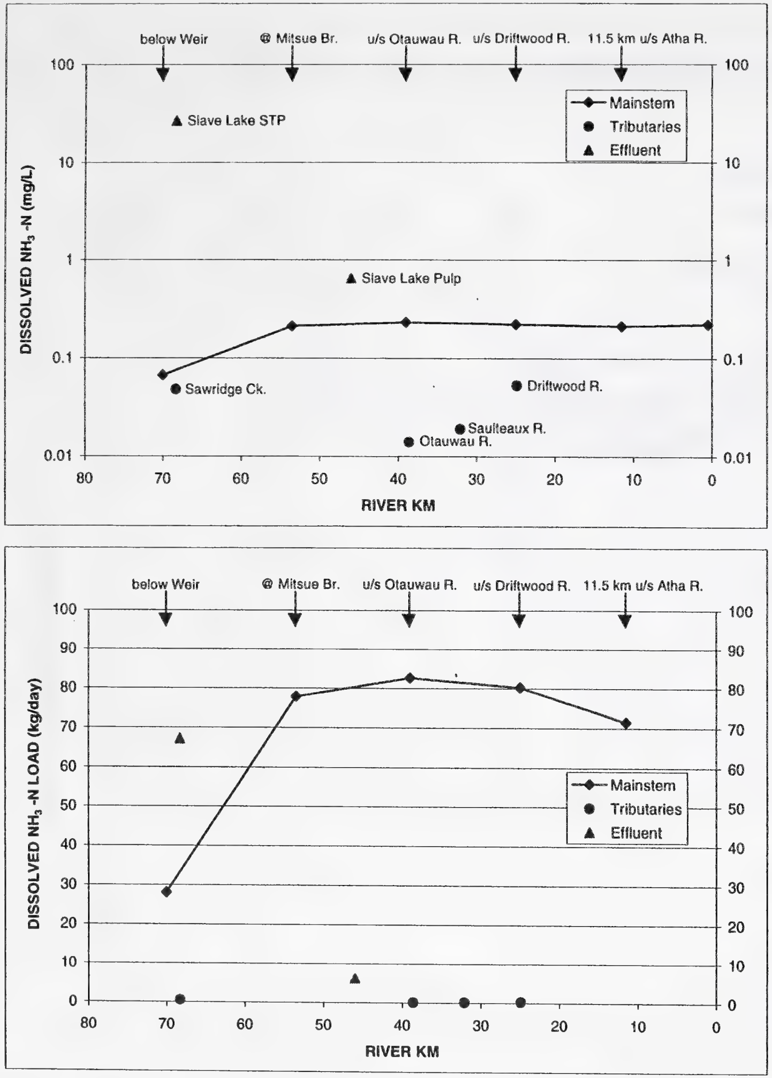


Figure 6a. Concentration and mass load of ammonia nitrogen during the synoptic survey of the Lesser Slave River, December 1999.

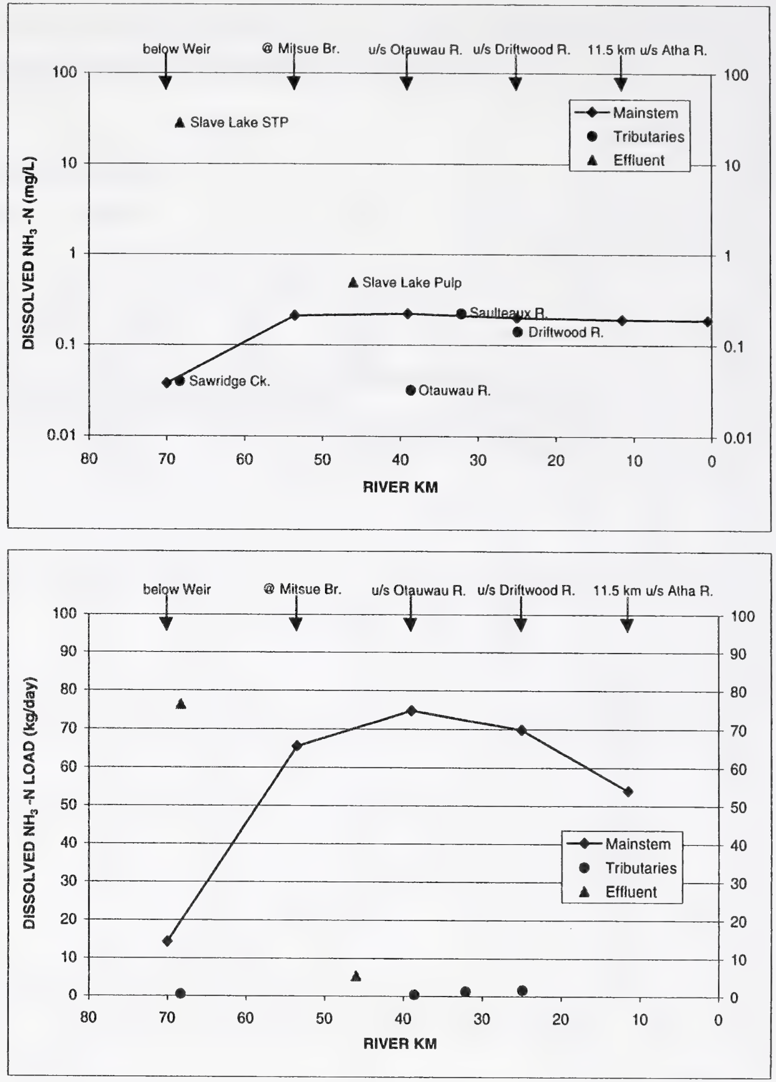


Figure 6b. Concentration and mass load of ammonia nitrogen during the synoptic survey on the Lesser Slave River, March 2000.

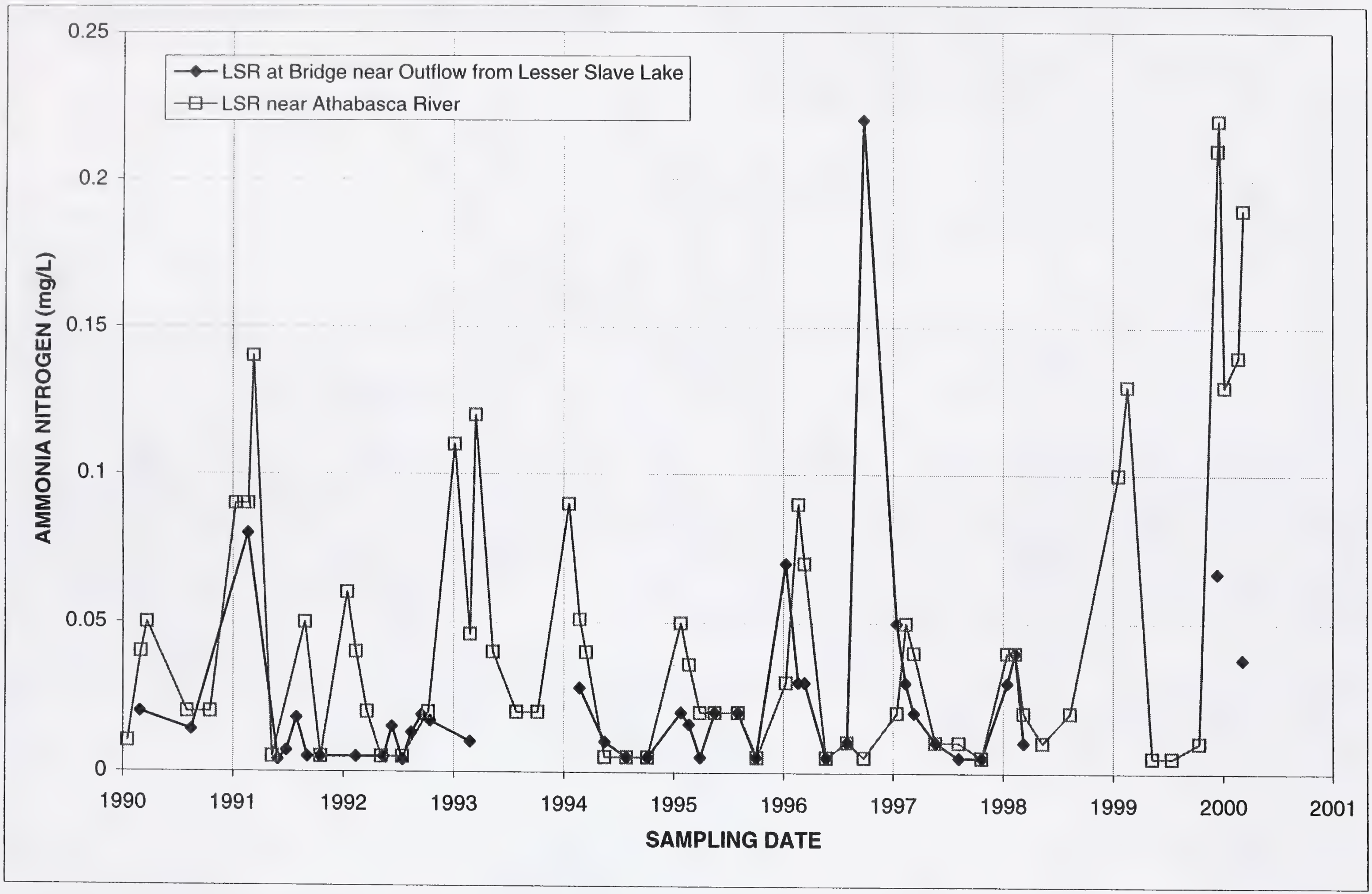


Figure 6c. Concentration of ammonia nitrogen at two long-term sites on the Lesser Slave River, 1990-2000.

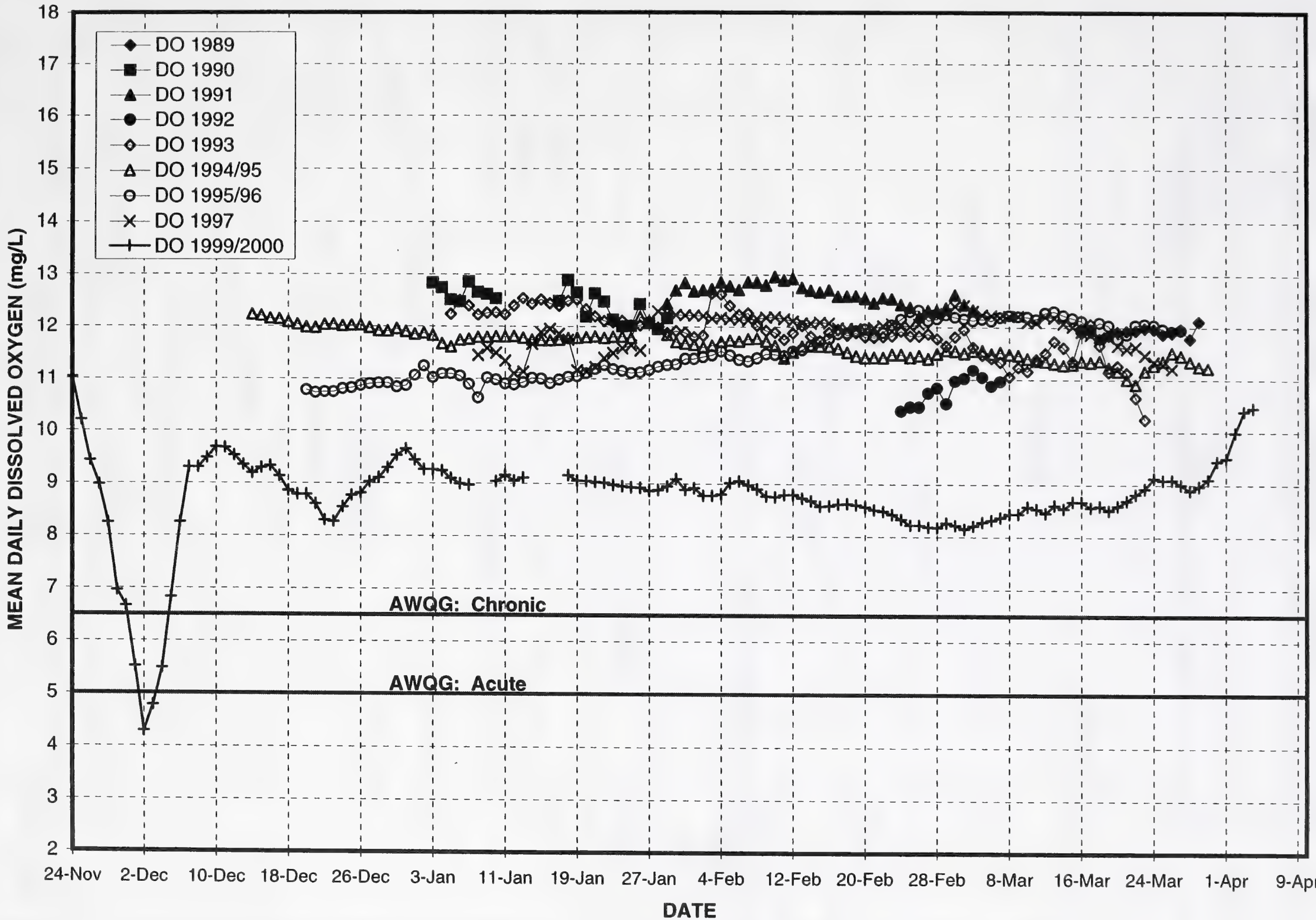


Figure 7a. Lesser Slave River near Athabasca River winter dissolved oxygen (recording meters), 1989-2000.

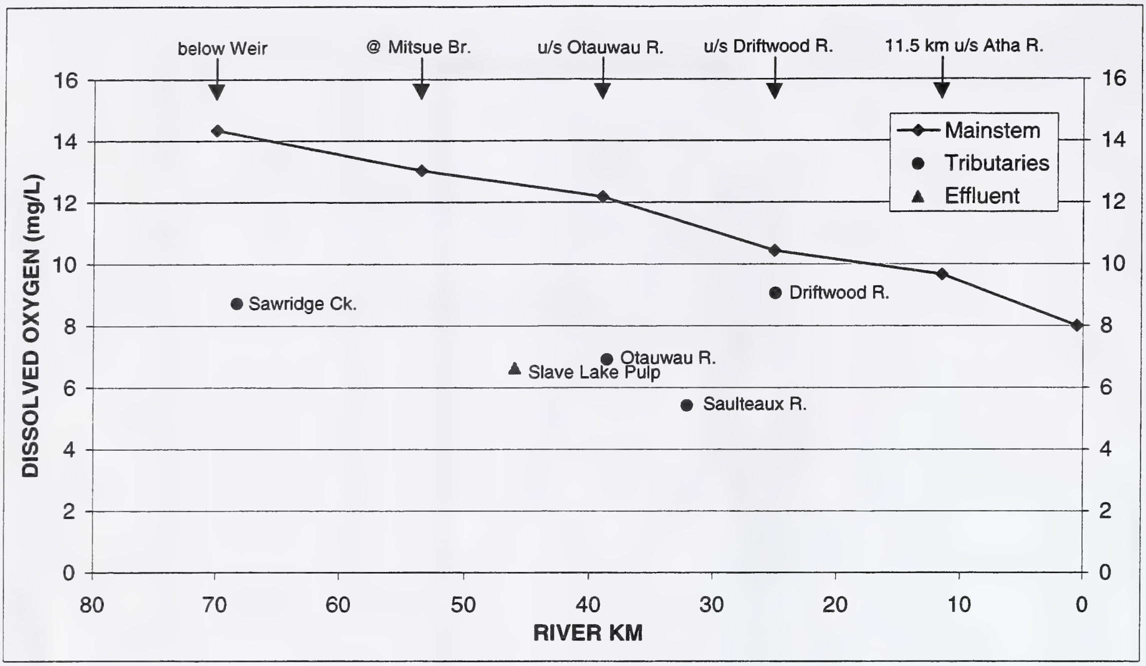


Figure7b. Concentration of dissolved oxygen during the synoptic survey on the Lesser Slave River, December 1999.

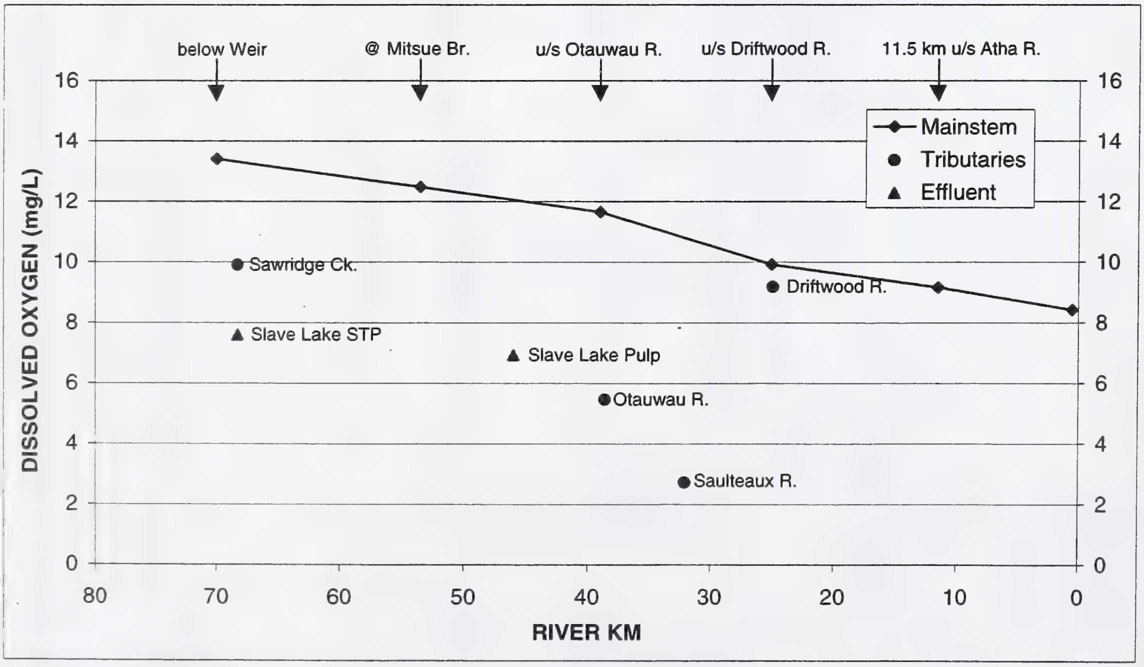


Figure7c. Concentration of dissolved oxygen during the synoptic survey on the Lesser Slave River, March 2000.

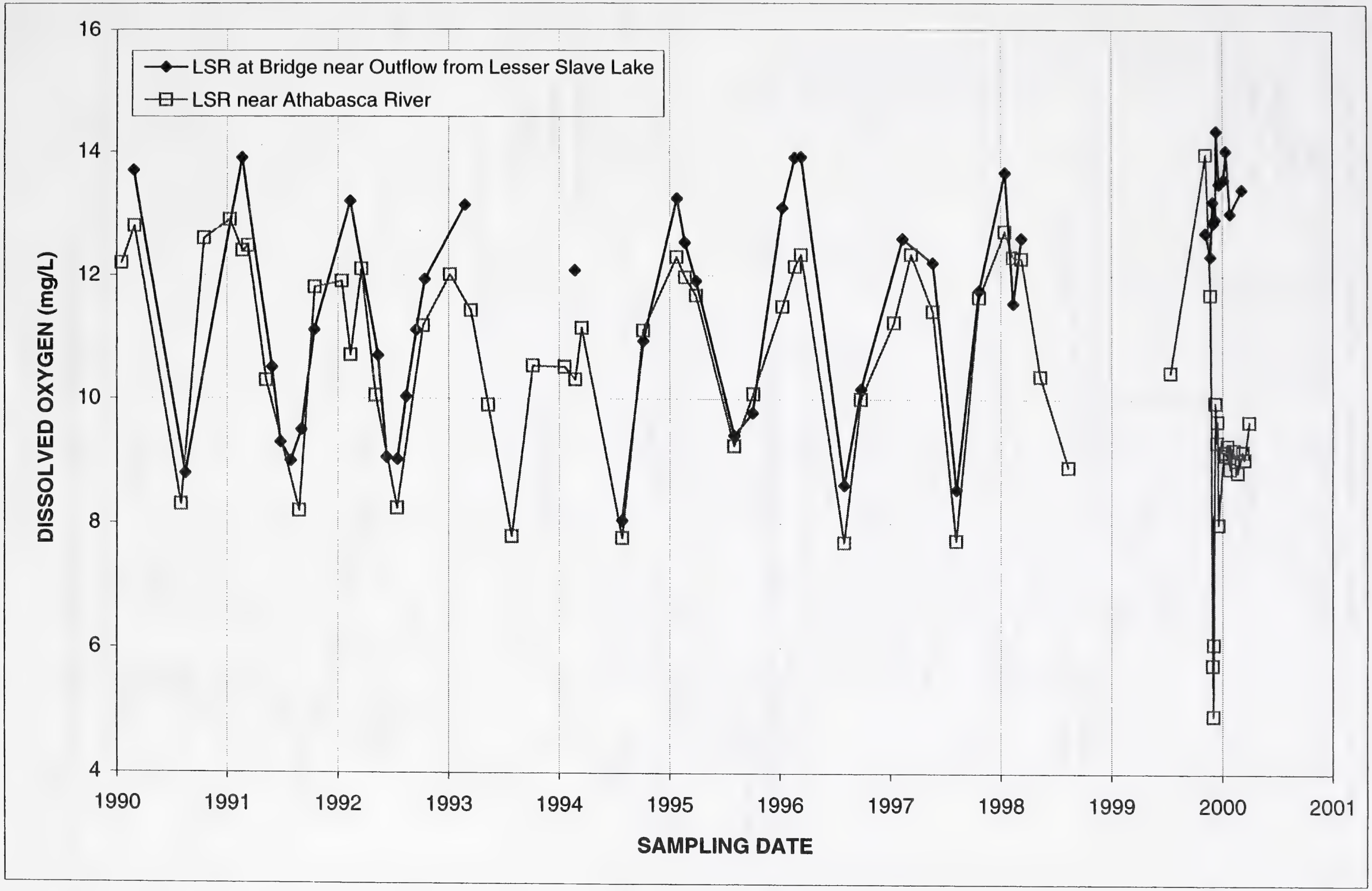


Figure 7d. Concentration of dissolved oxygen at two long-term sites on the Lesser Slave River, 1990-2000 (grab sampling).

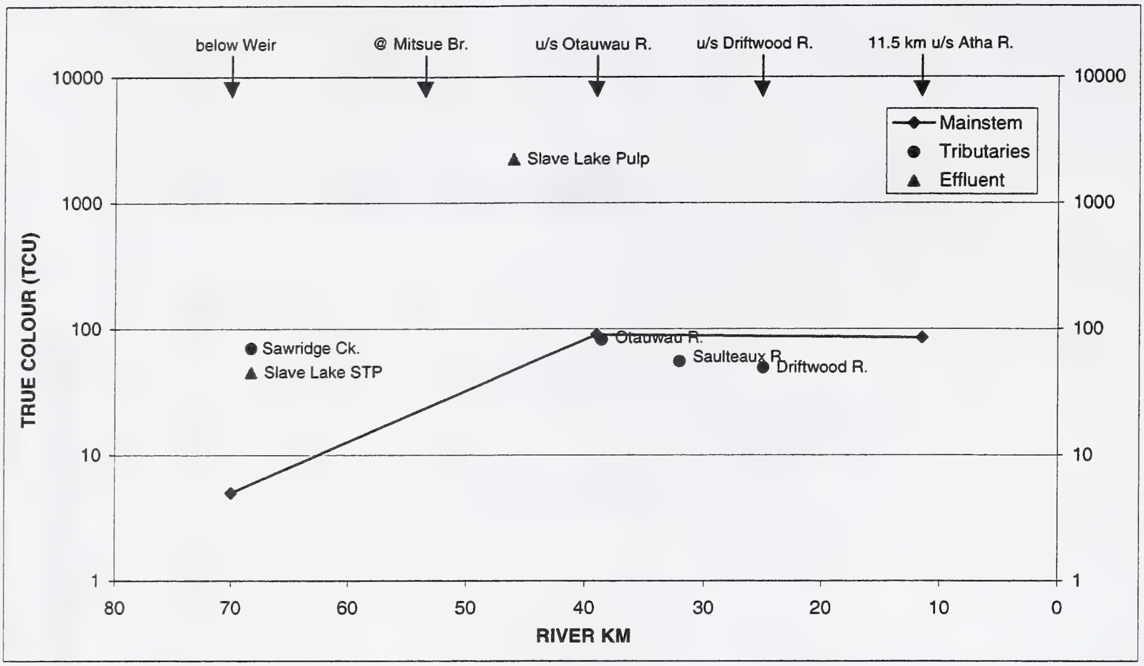


Figure 8a. True colour during the synoptic survey on the Lesser Slave River, December 1999.

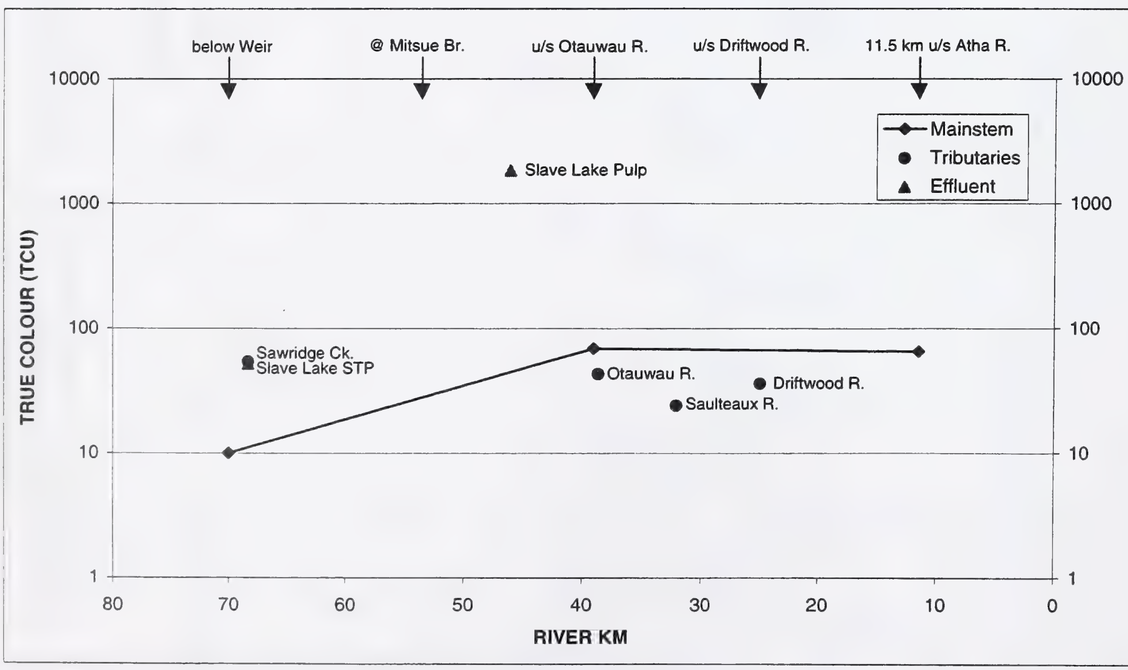


Figure 8b. True colour during the synoptic survey on the Lesser Slave River, March 2000.

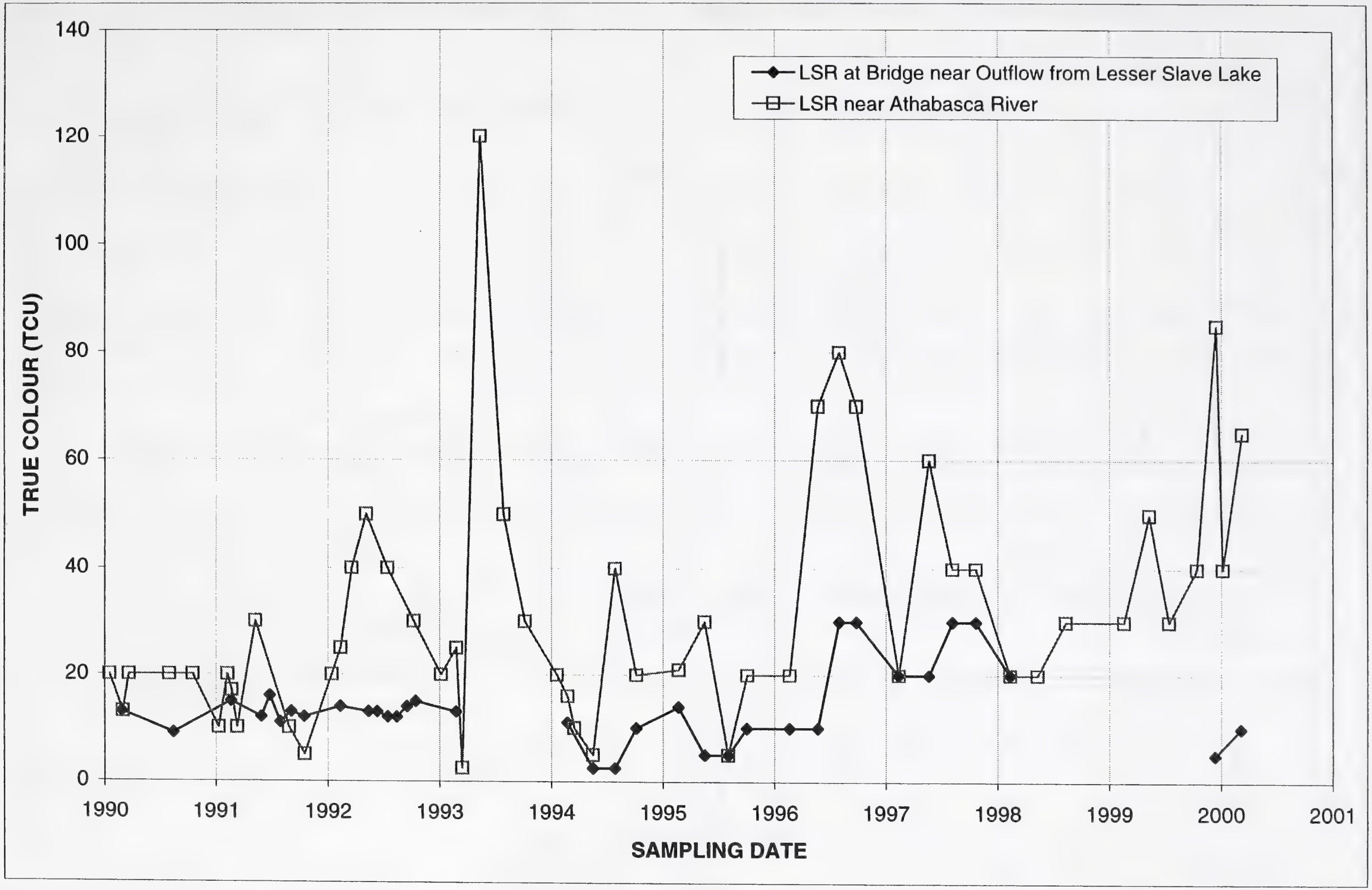


Figure 8c. True colour at two long-term sites on the Lesser Slave River, 1990-2000.

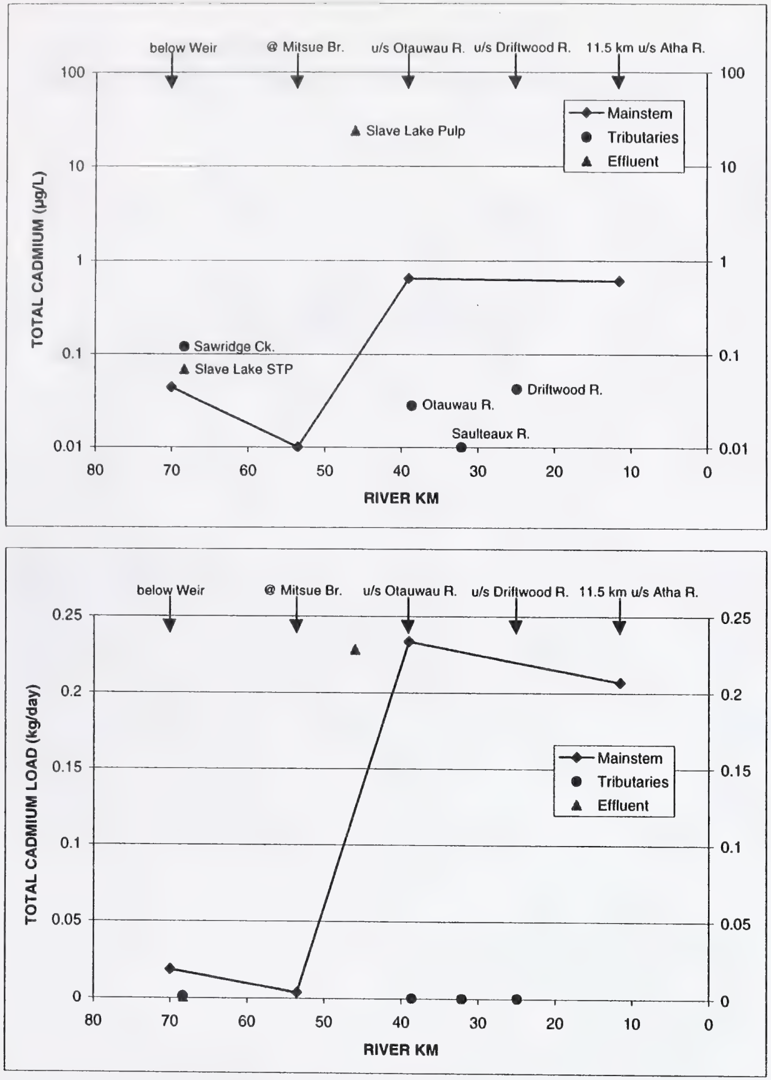


Figure 9a. Concentration and mass load of cadmium during the synoptic survey of the Lesser Slave River, December 1999.

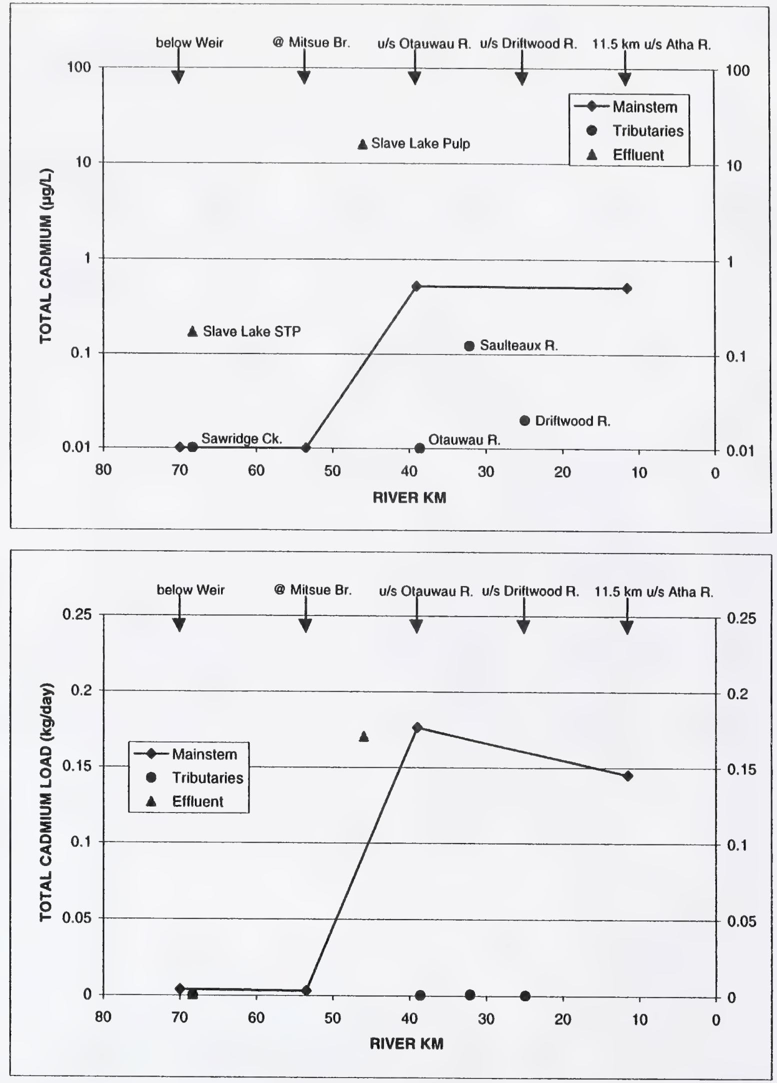


Figure 9b. Concentration and mass load of cadmium during the synoptic survey on the Lesser Slave River, March 2000.

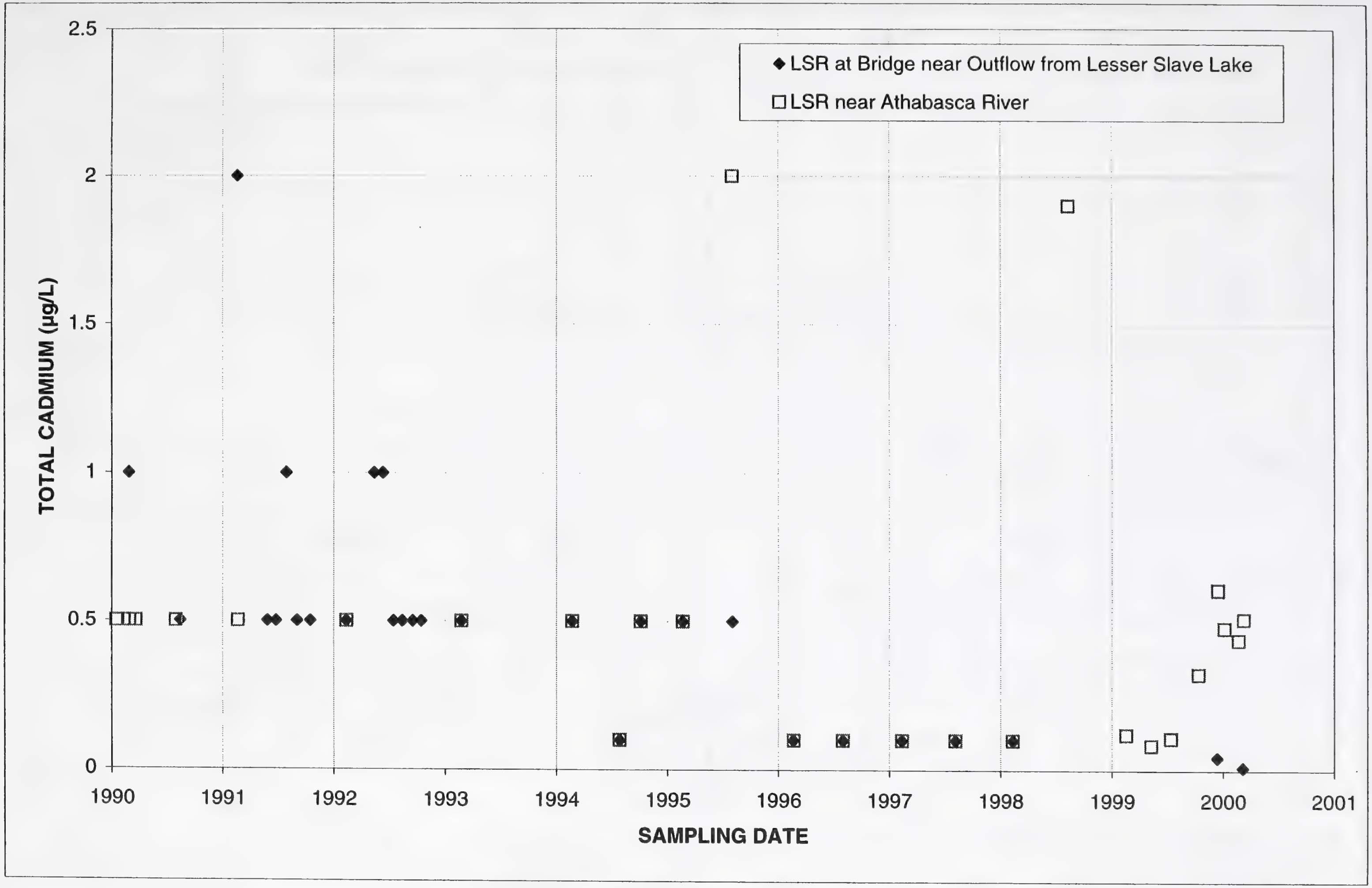


Figure 9c. Concentration of total cadmium at two long-term sites on the Lesser Slave River, 1990-2000.

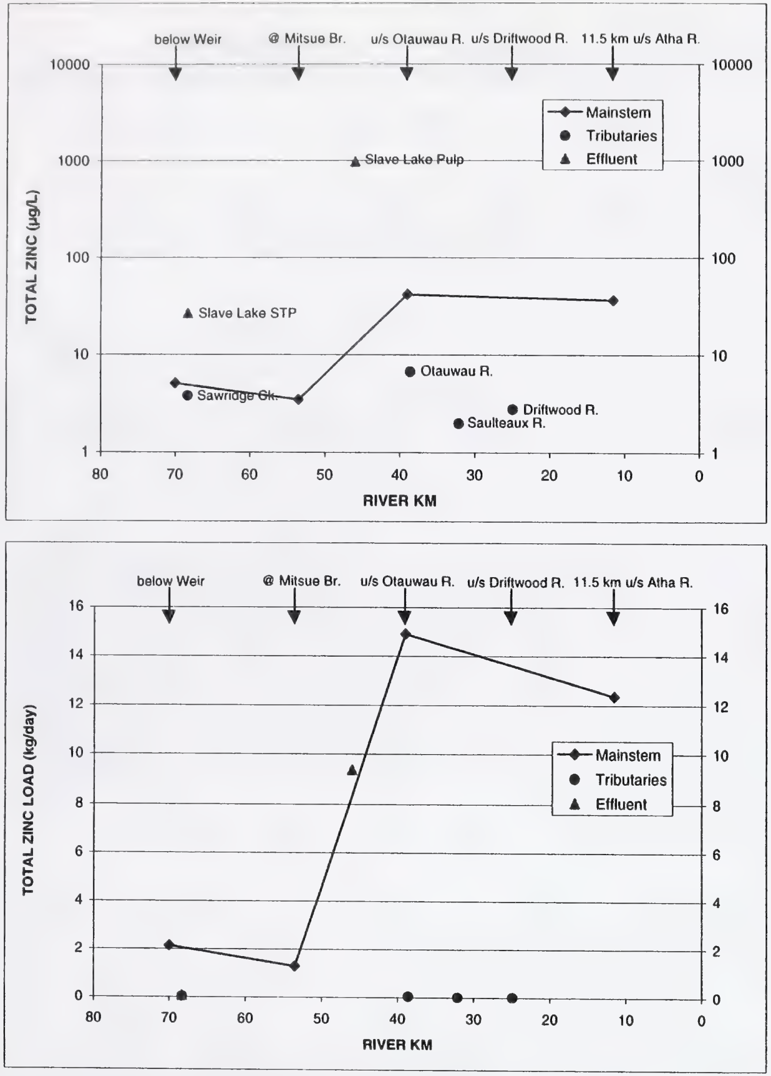


Figure 10a. Concentration and mass load of zinc during the synoptic survey of the Lesser Slave River, December 1999.

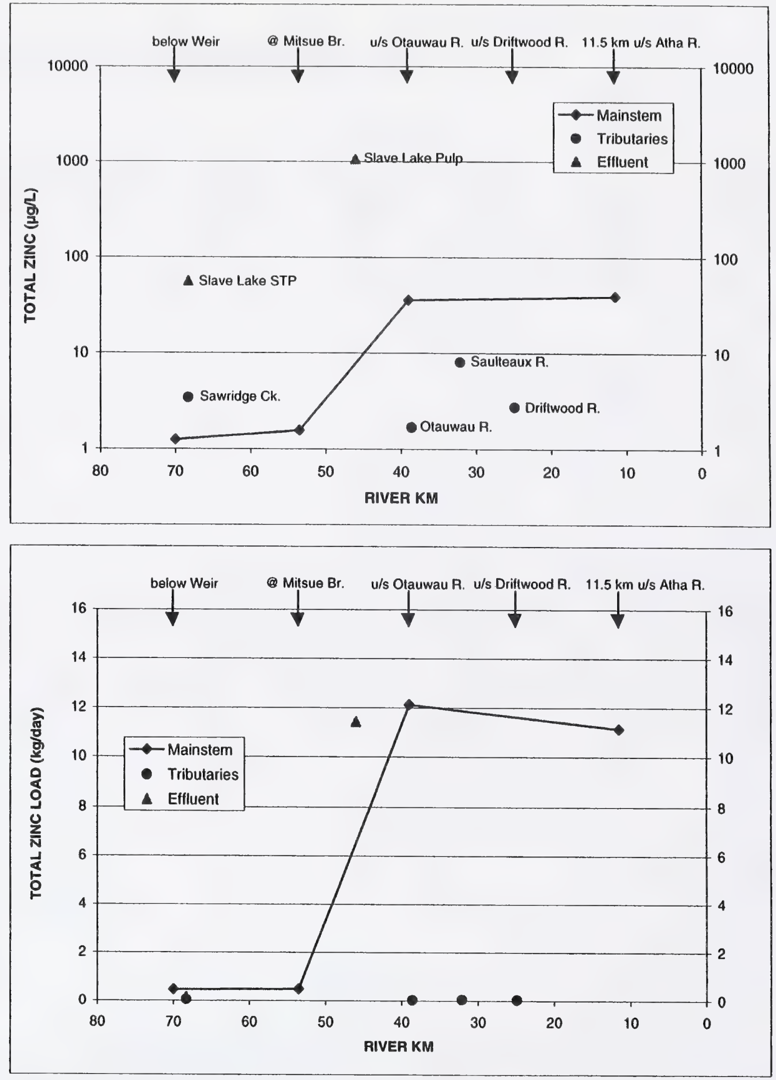


Figure 10b. Concentration and mass load of zinc during the synoptic survey on the Lesser Slave River, March 2000.

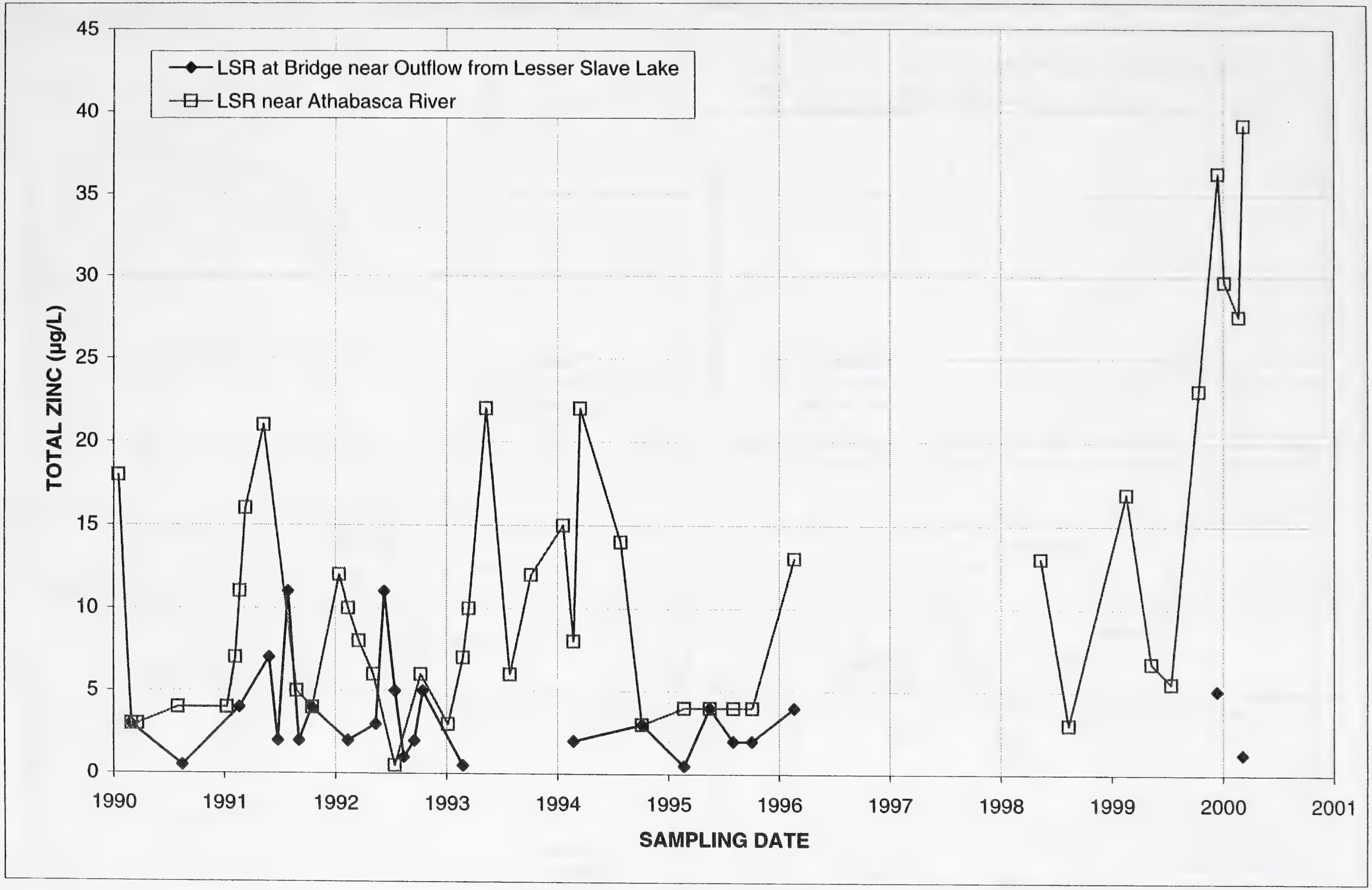


Figure 10c. Concentration of total zinc at two long-term sites on the Lesser Slave River, 1990-2000.

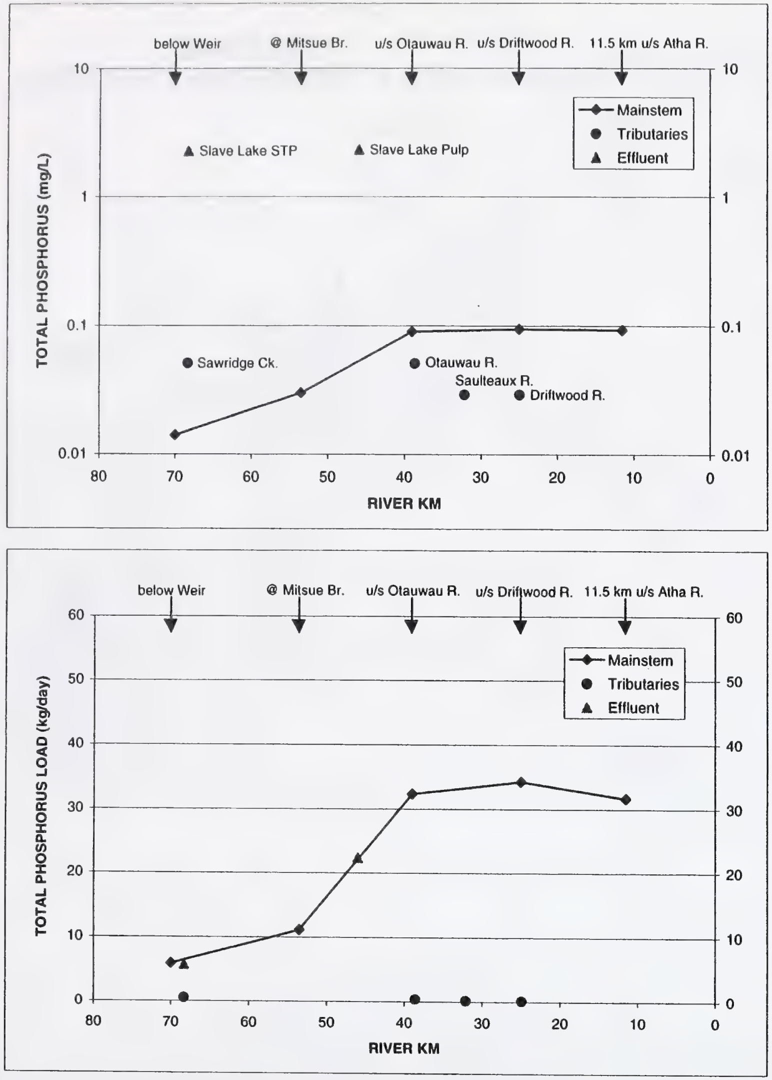


Figure 11a. Concentration and mass load of total phosphorus during the synoptic survey of the Lesser Slave River, December 1999.

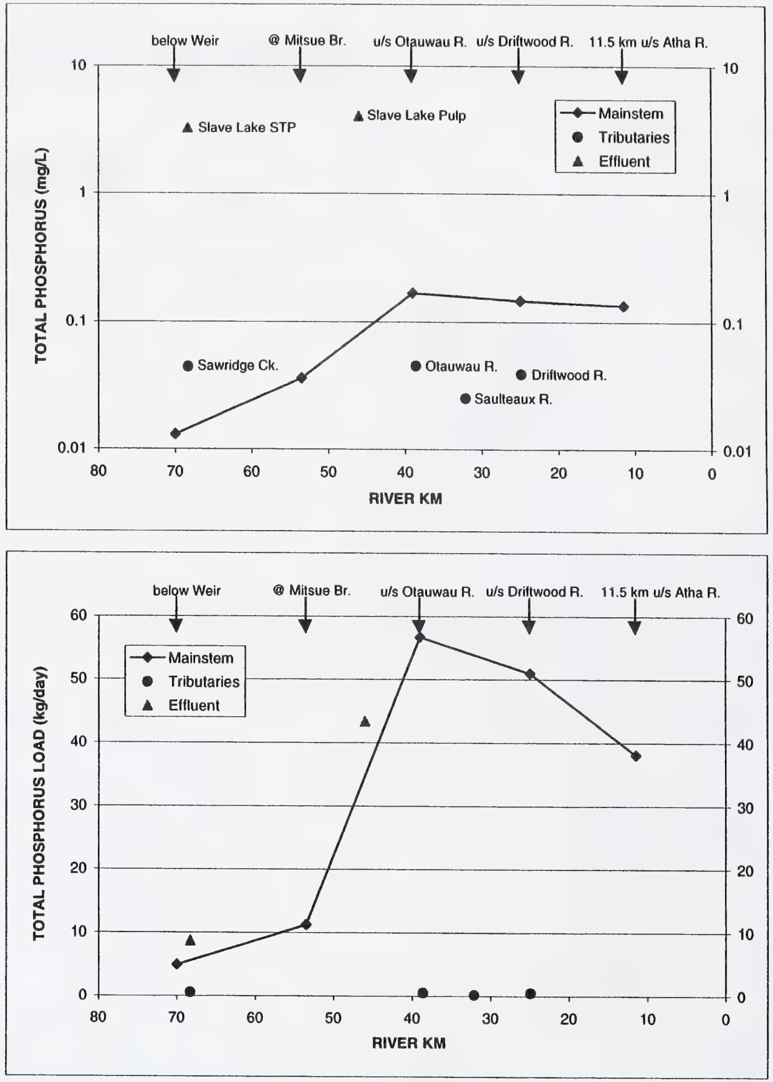


Figure 11b. Concentration and mass load of total phosphorus during the synoptic survey on the Lesser Slave River, March 2000.

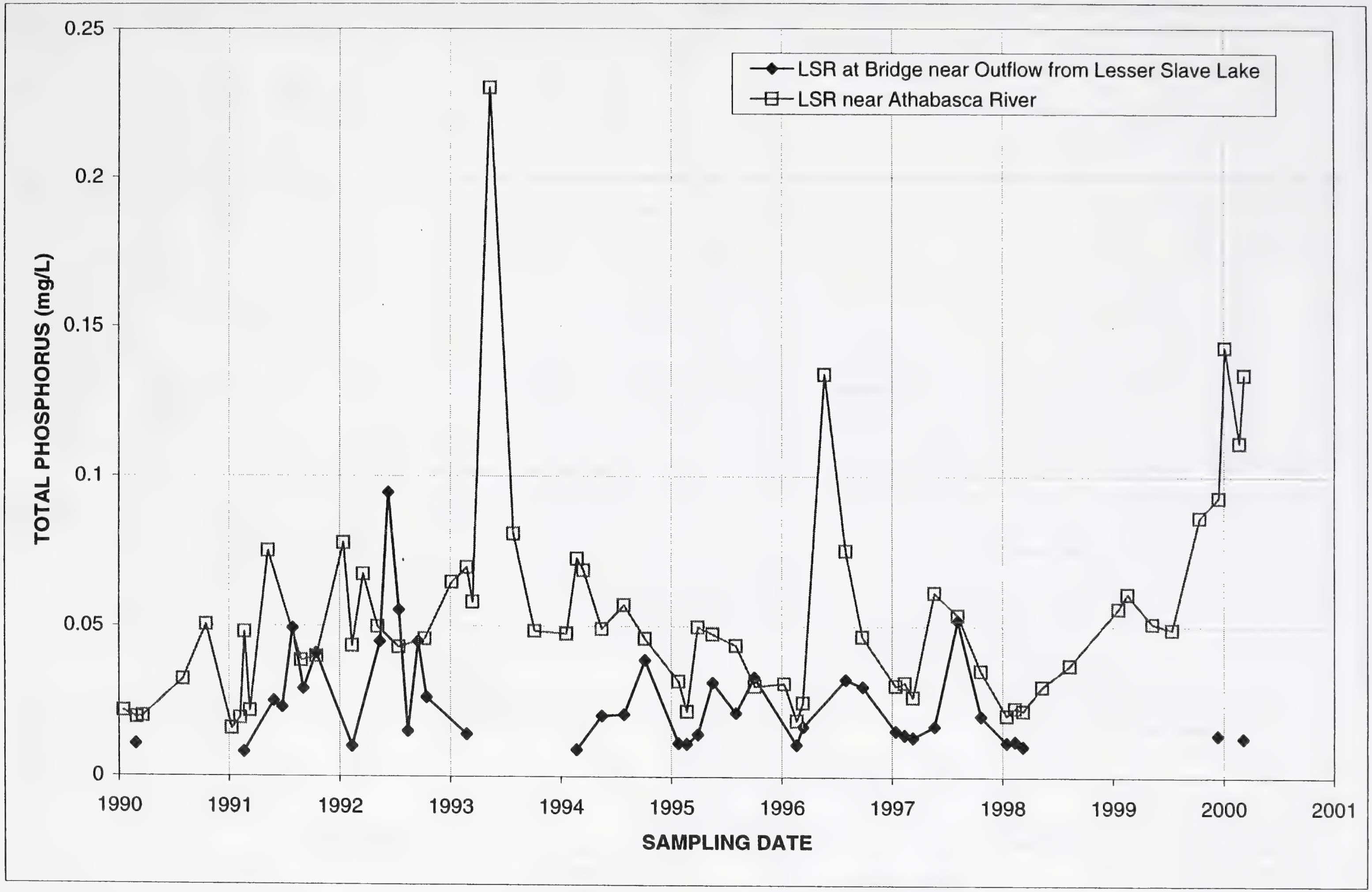


Figure 11c. Concentration of total phosphorus at two long-term sites on the Lesser Slave River, 1990-2000.

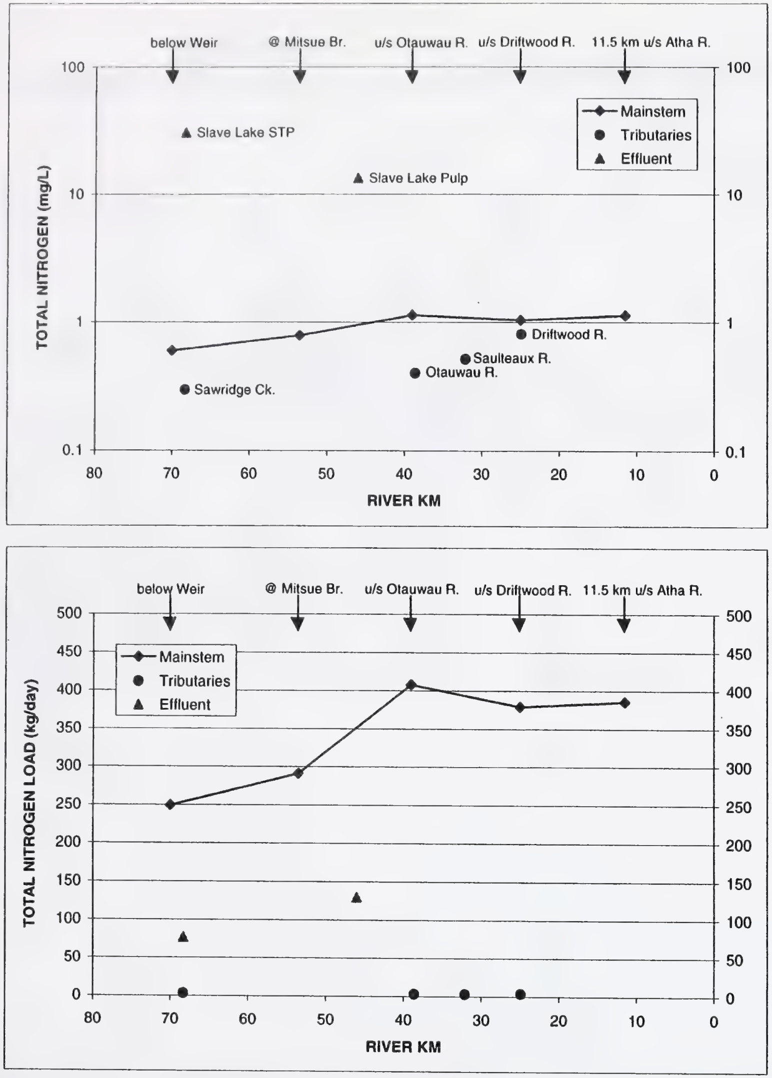


Figure 12a. Concentration and mass load of total nitrogen during the synoptic survey of the Lesser Slave River, December 1999.

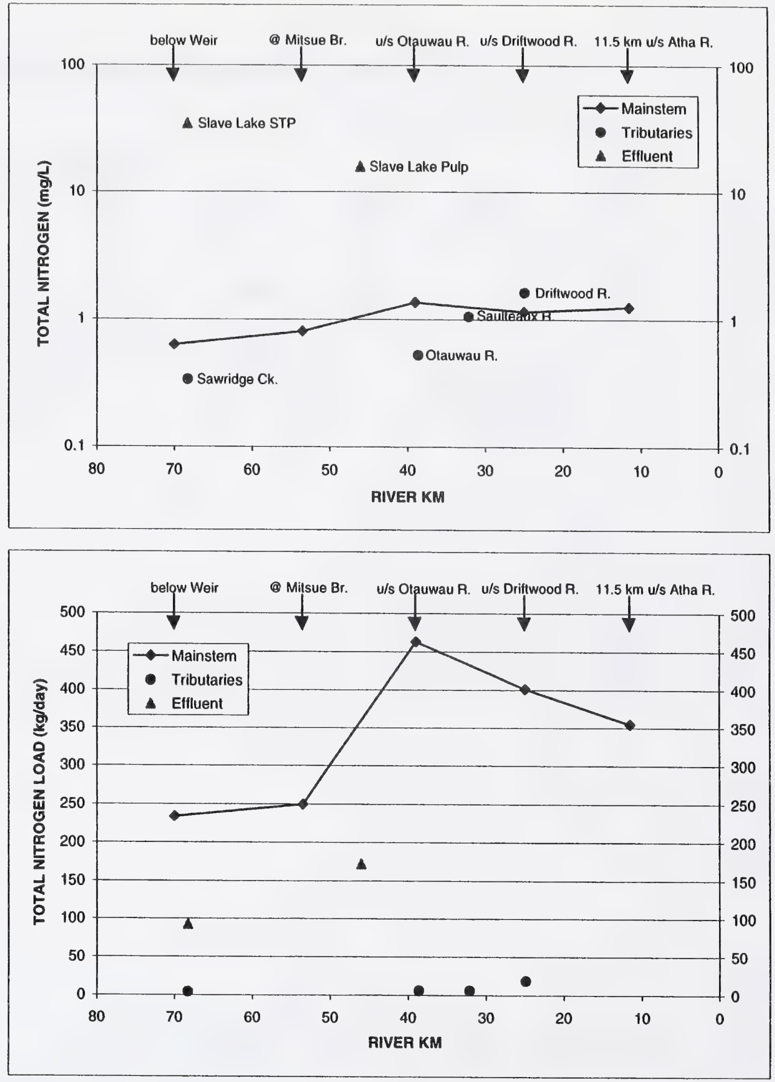


Figure 12b. Concentration and mass load of total nitrogen during the synoptic survey on the Lesser Slave River, March 2000.

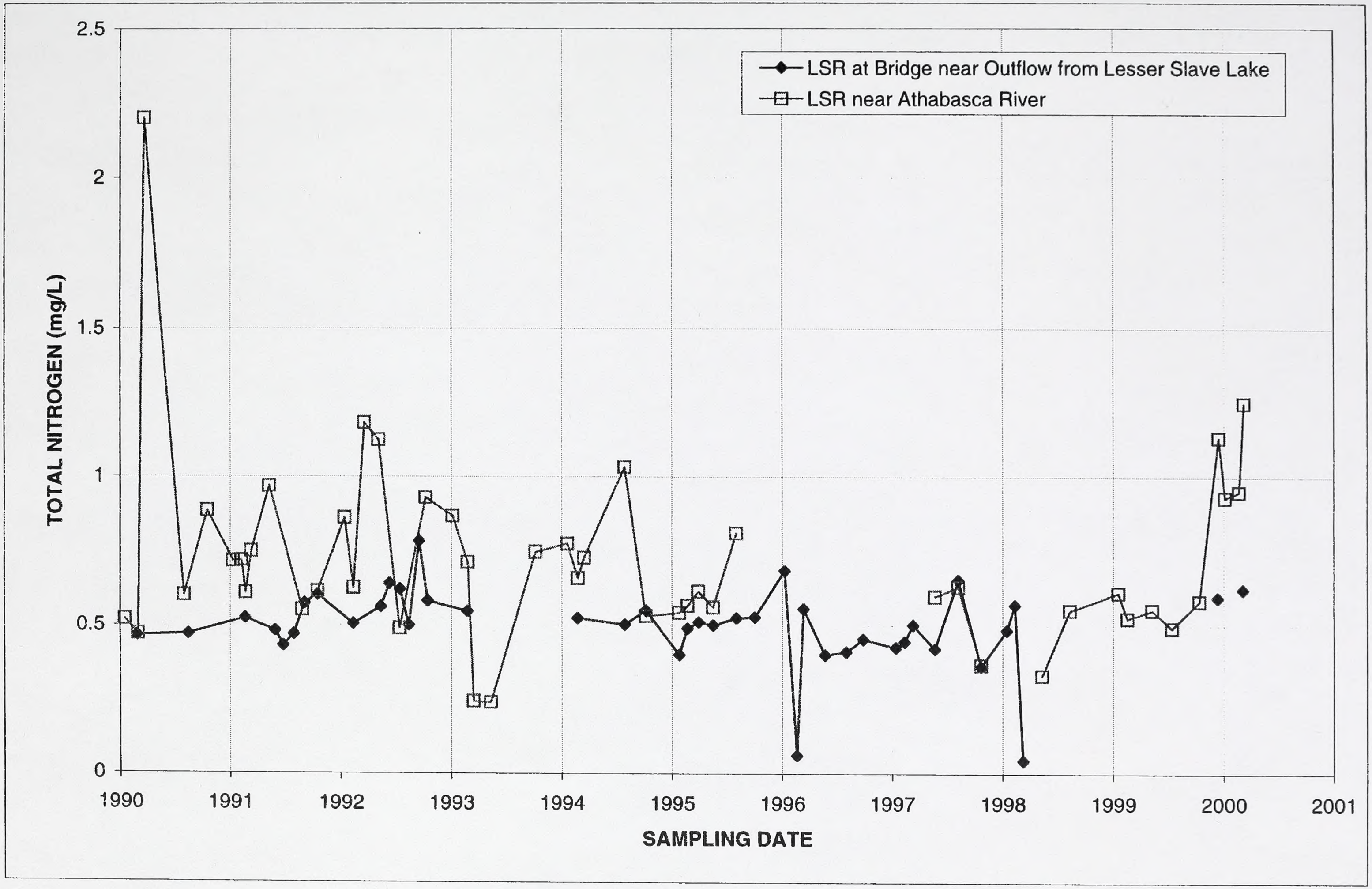


Figure 12c. **Concentration of total nitrogen at two long-term sites on the Lesser Slave River, 1990-2000.**